MANGROVE ECOSYSTEM BIODIVERSITY: A CASE STUDY

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सारांश

कोचीन नगर के उत्तरांचल में स्थित मंगलवनम के दलदली पारिस्थितिक तंत्र पर जनवरी - जून 2002 के दौरान किए इस अध्ययन में इस क्षेत्र की जीववैविद्यता - परिरक्षण संबंधों पर प्रकाश डाला जाता है. यह पारिस्थितिक तंत्र ज्वार-भाटा से प्रभावित है जिसकी वजह से प्रदेश निमग्न और अनिमग्न रहता है. पादपप्लवक बहुत होते हुए भी पानी में विलीन ऑक्सिजन का अंश कम देखा गया (3.5 मि ली). इसका कारण जलीय जीव जातों की अधिक संख्या है; पादपों द्वारा उत्पादित ऑक्सिजन इनके श्वसन केलिए लिया जाता है. इन दोनों के बीच वर्तमान असंतुलन का कारण मनुष्य के हस्तक्षेप से जोडा जा सकता है. इस असंतुलन से तंत्र की आम पौष्टिकता अधिक है. दलदली पौधों में *अविसेनिया मरीना* , *रिज़ोफोश म्यूक्रोनेटा* और *अकान्थस इलिसिफोलियस* प्रमुख थे. इन में अविसेनिया और अकान्थस पौधे मीठे पानी क्षेत्रों में ज्यादा पाए गए. पादपप्लवकों में सिलिकेट प्रभावित डयाटम जैसे नविकुलेसिए और कोसिनोडिसिए अधिक थे. जन्तुप्लवकों में कोपिपोडे ज्यादा थे. कीचडी नितलस्थ जीवजातों में पोलिकीट और डेकापोडे प्रमुख थे. सामान्य खारा पानी मछलियों जैसे *चानोस* , *लिजा, इट्रोप्लस* , *सिलगों, लेथ्रिनस* और *लूटजानस* की तरुण जातियाँ यहाँ अच्छी तरह पलती हुई देखीं. इसके अलावा झींगा और कर्कटों की कई जातियाँ भी यहाँ पाई गई. पक्षिसंकेत केलिए मशहूर इस परितंत्र में आम तौर पर पाए गए पक्षी जल काक, वाक-बगुल आदि थे. अन्य वृक्षवासी जीवियों में उडनेवाला फोक्स *डीरोप्स जैजेन्टस* प्रमुख था. अध्ययन से यह स्पष्ट होता है कि इस दलदलीय परितंत्र में जीव वैविद्यता कम होते हुए भी जीवजातों की सघनता अधिक है. कुलमिलाकर कह जाएं तो मानवीय हस्तक्षेप से पर्यावरण में अडचन हुए हैं साथ ही साथ स्थलीय पौधों की बढ़ती से दलदली भूमि में कमी भी.

ABSTRACT

Investigations on the biodiversity in relation to conservative and non-conservative parameters in the Mangalavanam mangrove ecosystem, located in the northern fringes of Cochin City have been carried out from January to June 2002. The mangrove ecosystem is regularly under tidal influence and hence submergence and emergence of land takes place depending on the tidal amplitude. The average dissolved oxygen of the water was found to be 3.5ml/l despite the fact, phytoplankton was abundant in the ecosystem. It reveals that respiratory demand of the aquatic biota has exceeded the photosynthetic oxygen production. The indirect relationship exhibited by the quantity of phytoplankton and oxygen is attributed to anthropogenic activities, which resulted in to the eutrophication of the mangrove ecosystem. The general nutrient load was at a higher level. The macrophytic vegetation was dominated by *Avicennia marina, Rhizophora mucronata and Acanthus ilicifolius.* The presence of *Avicennia* and *Acanthus* in majority of the area that showed decrease in salinity and more freshwater influx. The phytoplankton community was dominated by diatoms represented Naviculaceae followed by Coscinodisceae, which is evidenced by the presence of high quantity of silicate. The Zooplankton was dominated by copepods. Benthic community is dominated by the infauna such as polychaetes and decapods. Juveniles of common brackish water fishes, *Chanos spp., Liza spp., Etroplus spp., Silago spp., Lethrinus spp.* and *Lutjanus spp.*, and species of crustaceans like *Penaeus spp., Metapenaeus spp., Macrobrachium spp., Acetes spp., Metaplex spp., Sesarma spp., Uca spp.*, and *Scylla spp.*, have been found to be the residents of the mangrove ecosystem. Avian fauna comprises mostly little cormorants (*Phalactocorax niger*) and black crowned night heron (*Nycticorax nycticorax*). Other arboreal fauna is dominated by Indian flying fox (*Pteropus giganteus*). An evaluation on the biodiversity of the mangrove ecosystem in the light of the present investigations reveals that species diversity is less, but moderate population density of available species could be observed. To put it in a nutshell, human interventions on the environment has been detrimental and a general degradation of the ecosystem has been evidenced by the emergence of terrestrial vegetation and shrinking of the true mangrove areas.

CONTENTS

LIST OF TABLES

V. Statistical indices

LIST OF FIGURES

I. Physicochemical Characteristics Of Water:

II. Sediment Characteristics

III. Biodiversity

a) Phytoplankton

b) Zooplankton

c) Macrobenthos

IV Statistical indices

List Of Plates

1.INTRODUCTION

1. INTRODUCTION

The tropical coastal zone is a dynamic system in a state of continual adjustment as a result of natural process and human activities. The mangrove ecosystem is a unique association of plants, animals and microorganisms acclimatized to life in the fluctuating environment of the tropical intertidal zone covering more than 10million ha worldwide. The word 'Mangrove' originated from the Portuguese language 'mangue' means maritime bush. According to Blasco *et al.* (1975) mangroves are woody vegetation that fringes muddy saline shore and estuaries in tropical and subtropical regions. Mangrove forests are complex faunal and floral association of terrestrial and estuarine origin, inhabiting the intertidal, swampy areas of tropical protected coastal belts. These serve as distinct margin between land and sea. Mangrove swamps attract faunal components from adjoining terrestrial and aquatic ecosystems, in addition to harbouring many indigenous animal species (Macintosh, 1982). It has a worldwide circumtropical distribution, the highest concentration being located in the Indo pacific region (Padmakumar, 1983). Traditionally wetlands have been viewed as ecosystems associated with disease, difficulty and danger, but ecologists realize that those are amazingly productive and just waiting to be tapped.

The mangroves dominate almost $1/4^{th}$ of world's tropical coastline. The world's total mangrove area which spans 30 countries including various island nations is about 1,00,000 km^2 (Deshmukh and Balaji, 1994). In 1960's the total area of the Indian mangroves was estimated as 6,81,976 ha, in which nearly 45% occurs in Sunderban and the islands of Bay of Bengal (Blasco1975, 1977). In addition, $1/6^{th}$ of the mangrove of the country is available in Andaman and Nicobar islands (Chakaraborty and Naskar, 1988). Later Saengar *et al.*, (1983) recorded the total mangrove area as 3,56,500ha and according to a survey in 1992,the total area of Indian mangrove is 4,37,400ha, which include A&N islands. Deforestation and overexploitation of mangrove have resulted into the open marshy land of 1,00,000ha. Mangroves along the west coast of India are considered as highly degraded areas. (Blasco 1975, 1977). The coastal areas like Gulf of Kutch, Bombay coast and Cochin

Backwaters are the glaring examples of deforestation, reclamation, pollution as well as population pressure. (Untawale, 1984). According to Ramachandran and Mohanan (1987) until a few centuries ago, backwaters of Kerala were fringed with rich mangrove vegetation. An estimate, based on the authentic record of Blasco (1975) indicated that there were about 70,000 ha of mangroves in Kerala, which have become reduced to a few hundred hectares, largely confined to some estuaries and creeks. In Kerala, mangroves are distributed in Keeryad island, northern part of Cochin port and research farm at Puthuvypu, Mahe to Dharmadam/Kumbala coastal belt, Mallikad, Ashram, Pathiramanal, and in several other bits (Basha, 1991). Mangrove area of Kerala is estimated to be about 17Km^2 in 1992, of these 36% are in degraded and degrading condition (Basha, 1992). This is in comparison to the 700Km^2 of mangroves, which existed in Kerala earlier (Ramachandran, 1985)

The mangrove biota is a heterogeneous assemblage of terrestrial, estuarine, and marine organisms. Globally 60 species of true mangrove trees and shrubs are inhabiting and more than 20 littoral species are very often associated with this flora. Based on the height of the vegetation the forest plants can be classified into 3 groups.1) The widest trunk with the spreading crown found in species *Sonneratia* and *Avicennia* and less spreading crown found in the species of *Bruguiera* and *Rhizophora* which covers the top canopy of the forest. 2) Shrubs and small trees represented by the species of *Aegiceras, Excoecaria* and *Ceriops*. 3) Small shrubs and ferns such as *Acanthus, Aegiiotis*, and *Acrostichum*. The colonization of saline tolerant terrestrial species also contribute to the diversification of mangrove environment, which are *Calophyllum inophyllum, Thespesia populnea, Terminalia catappa, Prosopsis, Acacia planifrons, Casuarina equisetifolia* and *Pandanus tectorius*. The physiological adaptation of true mangrove plants are highly significant especially they are physiological halophytes and exhibit a capability of salinity tolerance, thick cuticle layered leaves and large mucilage cells. The formation of salt glands, viviparous germination, buttress silt roots, prop roots, knee roots and pneumatophores are the characteristic features of prominent mangrove flora. The network of root system helps in binding the nutrient laden soil. It is a unique environment in the face of the world. Like any types of the forest, mangrove forms the national wealth.

Mangrove systems are among the most productive natural ecosystems on earth .The rich productivity is achieved from the mangrove vegetation themselves by a huge amount of litter fall, algal colonies associated with the mangrove root surfaces and the moist floor, and the phytoplankton communities in the associated bay and lagoons, of mangrove forest. Green filamentous species of *Enteromorpha, Rhizocolonium, Monostroma* and *Ulva* are the diverse algal species colonized in the mangrove environment. The primary food source for aquatic organisms in most mangroves is in the form of particulate organic matter (detritus) derived from the decomposition of mangrove litter fall. The annual litter fall normally ranges from 10,000 to 14,000 kg/ha and it is estimated that insects consume about 20-25% of available leaf tissues (Deshmukh and Balaji, 1994). Krishnamurthy *et al* (1983) has estimated that the yield of mangrove-cum estuarine dependent fisheries of India is 30,000 tones of crustaceans per annum. Roughly about 60% of India's coastal marine fish species are dependent on the mangrove estuarine complex (Gopinathan and Selvaraj, 1996).

Some common fishes inhabit the mangrove ecosystem are *Liza, Mugil, Lates, Polynemus, Ilisha* and *Etroplus*. In Crustaceans like *Penaeus, Metapenaeus* and *Scylla* (mudcrab), the molluscan forms of *Crassostrea, Meretrix, Telescopium and Cerethedia* are commonly encountered in the mangrove ecosystem, plays an important role in fish and fisheries. Tanin liberated by the mangrove vegetation hardens egg case of fin and shellfishes and provide better survival for hatchlings while wax from mangrove leaves and hymenopteran's hives controls predatory aquatic insects. Mangroves are rich in yeast concentration and their enzymatic activities breakdown the cellulose and the hemicellulose from the mangrove litters and pectin from shells of dead crustaceans respectively making carbohydrates, protein etc. readily available to the growing prawns and fishes which feed on detritus. Mangrove also purifies the aquatic system from hydrocarbon pollution.

Ecological features influence heavily in the zonation of mangrove ecosystem. Temperature influences the proliferation of mangrove vegetation in the early stages. Tidal flow and salinity effect the dispersion and zonation of the ecosystem. Tidal amplitude determines the landward extension of mangroves on flat coast and the productivity of the mangrove ecosystem, which is also related to

freshwater supply by rainfall. The litter fall is influenced by high wind velocity. The mangrove soils are generally slightly acidic, the anaerobic condition in the soil helps the sulphate reducing bacteria to produce hydrogen sulphide. The characteristic black/gray colour soil is due to the reduction of ferric compounds to ferrous sulphides (Deshmukh and Balaji.1994)

Mangroves serve as a natural barrier against the intrusion of the sea by dissipating the wave action and preventing soil erosion. It also helps in the productivity of coastal waters by trapping the nutrients drained off from the uplands, which otherwise would have found their way into the deep sea. Humans have also been residents of mangrove wetlands for centuries. The mangrove environment provides native populations with a seemingly endless variety of derived products: timber, thatching, charcoal, medication, and animal fodders (de la cruz, 1979). The mangrove system also yields an abundant supply of food, fish and prawns from the shore zone, bird's egg, honey and edible fruits from forest areas (Macintosh, 1982).

It is generally observed that mangroves are the breeding, feeding and nursery grounds for the larvae and juveniles of many commercially important species of finfish, crustaceans and shellfish. According to Kjerfve (1997), these wetland ecosystems are among the most productive and diverse in the world, and more than 80% of marine catches are directly or indirectly dependent on mangrove and other coastal ecosystems worldwide. The high productivity resulting from mangrove litter fall supports a host of detritus feeding animals such as amphipodes, mysids, harpoticoids, molluscs, crabs, and larvae of prawns and fishes. Mangrove is a rich source of antibiotic enzymes and other metabolites of commercial value. This also helps to degrade and assimilate pollutants, pesticides, and other chemicals, thus making the aquatic environment safe for other marine life. Besides serving as an excellent breeding ground for a variety of fish, the micro flora as well as the diverse presence of zooplanktons help in the growth and development of common fishery. Therefore, nudefication of mangroves are not only destroying genetic diversity but also important bio-reserves. The lack of awareness over the alarming depletion of mangrove forests in the state through want on destruction has led to fear over whether these seashore rain forests, which provide a vital habitat for a wide variety of marine and terrestrial animal and plant life, would soon become extinct.

Anthropogenic activities in the mangrove ecosystems have been increased manifold and coastal zone is home to 65% of the global population. Population growth and migration to coastal areas and poor management have lead to the depletion and destruction of mangrove areas. The total mangrove area has been shrunken to nearly to half due to the demographic shift in coastal areas, coupled with the pressure from rapidly expanding construction and industrialization during the past few decades. Altogether the human interventions put mangrove ecosystems in Asia especially in India under threat of profound destabilization with a potential loss of resources and a reduction in resource production. Mangroves play a significant role in coastal stabilization, promoting land accretion and fixation of mud banks, besides helps in dissipating winds, tidal and wave energy etc. According to Krishnakumar (The Hindu, March 24,2002) Mangalavanam, the mangrove under the present study is facing the growing threat of oil pollution by which the migratory avian fauna had also decreased over the years. This mangrove soil and water once supported abundant residents and migratory organisms, including numerous fishes, molluscs and crustaceans that are of economic importance. The present study is contemplated and is an effort to evaluate and portray the present biodiversity of Mangalavanam, a mangrove in the northern fringes of Cochin City, which has been subjected to considerable anthropogenic activities and presently protected by Kerala forest department for restoration and declared as a bird sanctuary in the name of famous Indian ornithologist Dr Salim Ali.

2.REVIEW OF LITERATURE

2.REVIEW OF LITERATURE

Mangrove ecosystems around the world have been extensively investigated by a number of researchers. Presently an attempt has been made to list out some of the important works on mangrove ecosystem in the world in general and particularly in India. A concise account of the Kerala mangroves could be found in the work of Troup (1921). Gamble (1915-1936) also dealt with the mangroves of Kerala coast. In 1940, Navalkar studied the ecology of Indian mangrove plants. The physical parameter of mangrove soil was studied by Navalkar in 1947. Navalkar and Bharucha (1948) estimated pH of seawater and corresponding soil solution of the mangroves. Ramkanna and Sahana (1950) stated that the mangrove species extent remarkable affinity towards Potassium in the carbohydrate synthesis. Tomlinson (1957) explained the relationship between mangrove vegetation, soil texture and reaction of surface soil after exploring saline swamps in Sierra Leone. Qureshi (1957) portrayed the botanical structure and features of mangrove forests in Bombay state. Seasonal variations in the total biomass and organic matter of the plankton in the marine zone of the Vellar estuary were examined by Seshadri (1957). Hart (1959) reported that the soil acidity of mangroves is due to the activity of bacteria on oxidizable sulphur. Deer *et al.* (1962) observed that the mangrove sediments would get the addition of potassium through vegetal parts of mangrove flora. Sidhu (1963) explained various ecological parameters on Indian Mangroves. Macnae(1968) provided the information on the fauna and flora of the mangrove swamps and forests in the Indo-West pacific region. The contributions of mangrove swamps to Florida fisheries were described by Heald and Odum in 1970. Sasekumar (1974) observed the distribution of macro fauna in a Malayan mangrove shore and stated that the CO_2 arising from decomposition of organic matter and from animal respiration also lowers the pH values in the soil. Jena and Chatterjee studied the fishing aspects of Sunderban Mangroves in 1974. Joshi and Jamale (1975) described the ecological parameters of mangroves in Terekhol and Vahistri river mouths.

Blasco, Carakini, Chandran and Thanikaimoni(1975) has given an authentic record and a detailed picture about the zonation and area of various Indian mangroves. Sunderraj *et al.* (1975) studied the correlation between the nutrient and plankton of the backwater mangrove environment. Jhingran (1975) Kurian and Sebastian, (1976) & Parulakar (1985) discussed the prospects of aquaculture in Mangrove ecosystem of India. Frith *et al.* (1976) explained about various soil characteristics and vegetation of mangrove forest of Sunderban in India and found the pH was fluctuating between acidic to alkaline. Untawale and Parulakar (1976) conducted some studies on the ecology of estuarine Mangroves of Goa and reported that nutrients especially inorganic phosphate exhibits an inverse correlation with sediment load. Physicochemical characteristics of Cochin backwaters were estimated by Cheriyan (1969); Sankaranarayan and Qasim (1969); Shyanmma and Balakrishnan (1973); Sreedharan and Salih (1974);Remani,*et.al* (1980). Turner (1977) gave an account on intertidal vegetation and commercial yields of penaeid shrimps. Pillai (1977) explained the distribution and seasonal abundance of macro benthos of the Cochin backwater system. Chapman (1977) emphasized about the significance of favourable temperature for establishment and development of mangroves. Sunderrraj (1978) evaluated the suitability of Mangrove biotope for brackish water aquaculture. Bohra Ali and Dwivedi (1978) observed the diurnal distribution of photosynthetic pigments and plankton in relation to environmental parameters in Malad creek. Sankaranarayanan *et al.* (1979) observed the Organic carbon, Phosphorus and Nitrogen parameters of Cochin backwaters and found high organic carbon content in the system. UNESCO (1979) published a book on Human uses and management implications of the mangrove ecosystem. Macintosh (1979) described the predation of fiddler crabs and distribution of various other estuarine crabs. Untawale (1979) presented a technical report of mangroves of Asia and Pacific and their status and management implications. Achudhan kutty and Sree kumaran Nair(1980) investigated the mangrove swamps and stated that they serve as fry source for shrimp and fish culture.

Dwiwedi and Padmakumar (1980) and Padmakumar (1984) have investigated the benthos of mangroves in Bombay with reference to sewage pollution. Matondkar *et al.* (1980) explained about the seasonal variations in the microflora from mangrove swamps of Goa. Pillai and Appukuttan (1980) have made

observations on the molluscan fauna of the mangroves in south east coast. Sasekumar (1980) prepared the status report of mangrove ecosystems in South East Asia and reported about the impact of pollution in Malaysian coastal belt. Bhunia and Choudhury (1981) and Nandi *et al.* (1983) studied the benthic macro fauna of Sagar Island in Sunderbans. Macintosh (1982) explained about the significance of fisheries and aquaculture in mangrove swamps in Indopacific region. Odum, Ivor and Smith (1982) explained the ecology of the Mangroves of South florida. Anon (1982) projected the detail account about the Indian Mangroves. Brand (1982) explored the possibilities of mariculture in the mangrove lagoons of Bajcalifornia in Mexico. Saenger (1982) had given the account of Australian Mangrove ecosystem's function and management. Padmakumar (1983) studied the ecology of mangrove swamps near Jhugu beach in Mumbai with reference to sewage pollution. Saenger and Heger (1983) explained the global status of mangrove ecosystem. Boto and Wellington (1983) monitored the phosphorus and nitrogen nutrient status of Australian mangrove forest and concluded that mature leaves of mangrove plants are useful indicators of mangrove forest nutritional status. Andrews, clough and Muller (1984), cited the managerial aspects of mangroves. Kurian (1984) reported the occurrence of *Acanthus ilicifolius*, *Avicennia alba*, *Rhizophora spp.* and *Bruguiera spp.* in Cochin estuary and also observed the larval forms of some species of fishes and prawns in the area. Snedaker *et al.* (1984) and Natarajan (1984) stated that the rural and urban development is responsible for reclamation of roughly 200,000ha of the total mangrove area along the Indian coast, which has positively created manifold problem and also affected the near shore fishery production. Jones (1984) stated that species of the Ocypodidae and Grapsidae families have morphological and physiological adaptations to temperature and salinity, which enable them to survive in all mangroves habitats. Untawale (1984) described the mangroves status in India and their multiple uses and practices in UNESCO project report. Muniyandi (1985) studied the biological aspects of Pichavaram mangroves. Palaniappan *et al.* (1985) studied the distribution and abundance of zooplankton in Pichavaram mangroves. Rajagopalan *et al* (1985) studied the mangrove biotopes of India in relation to ecological aspects. Kannan (1985) gave an account of the microplankton profile in the Pichavaram Mangroves. Chakaraborty and Chaudhury (1985) studied the distribution of fiddler crabs in Sunderbans. Kasinathan *et al.* (1985) conducted research on molluscan fauna of Pichavaram mangroves. Joshi *et al.* (1985) observed

the chemical characteristics of Gujarat mangrove areas. Ramachandran *et al.* (1985) attempted a study on the mapping, inventory and some environmental aspects of mangrove ecosystems in the Kerala state.

Matilal (1986) studied on soil parameters and vegetation of mangroves in Sunderban forest, India and also reported that pH varied from 7.9 to 8.4.Community structure and assemblage of economically important benthic penaeid and non penaeid juvenile prawns from the mangrove biotope in Portonovo has been studied by Sambasivam and Krishnamurty (1986). Shanmugam *et al.* (1986) conducted investigations on the biomass and composition of zooplankton from Pichavaram mangroves, south east coast of India. Ramachandran *et al.* (1986) conducted a detailed survey along the entire coastal stretches of Kerala and reported about 39 species of mangroves and mangrove associates; include some new species that were not reported earlier. Rajagopal *et al.* (1986) studied the Mangrove ecosystem of Cochin Backwater, Killai backwater and Andman & Nicobar Islands and stated that generally good production rate observed in the mangrove areas. Jeyaseelan and Krishnamurthy (1986) investigated the role of mangrove forest of Pichavaram - as fish nurseries. Bopaiah and Neelakandan (1986) reported that those mangrove areas are effectively influencing the seed resource of commercially important fishes and prawns. Bhosale (1986) explained about the biology, utilization and conservation, of Mangroves. Anon (1987) reported distinct aspects of Indian mangroves. The fungal activity in Mangalavanam was studied by Prabhakaran *et al.* (1987). The isolated fungi showed phosphate solubilizing capacity indicating possible role of these active fungi in the nutrient generation of the ecosystem by solubilizing insoluble phosphorus compounds and making them available to other organisms. Silas (1987a) stated the significance of the mangrove ecosystems in the recruitment of fry and larvae of finfish and crustaceans along the east coast of India particularly the Sunderbans. Silas (1987b) explained the management strategies of mangroves and opined that biologically and economically one of the most important aspects of man-mangrove interaction is the mangrove dependent or associated capture fisheries and aquaculture. Tarlochansingh (1987) described the issues on mangrove and aquaculture striking a balance. Aksornkoae (1988) covered the issues on mangrove habitat degradation at Ban Don Bays, Thailand. Chakaroborty and Naskar (1988) studied the role of mangrove in estuarine fishery development. Chakarabarty

(1988) conducted ecological investigations in West Bengal and North Bengal mangrove forests and recorded some prominent evidence for generic and species diversity of animal-vegetation dynamics of Sunderban forests. Gopalakrishnan *et.al.* (1988) analyzed the phytoplankton and zooplankton parameters in relation to hydrography and nutrient in the prawn fields adjacent to Cochin mangrove area. Nutrient content in the leaves were generally higher than that of other components of the litter (Healey *et al.* (1988)]. Chaudhuri (1988) expressed biological destruction in the aquatic and mangrove environment. Seralathan (1988) estimated the phosphorus content and discussed the factors responsible for phosphorus fixation in mangrove environments. Sinha *et al.* (1988) experienced a new stylet bearing nematodes in the Gangetic estuary. Patra *et al* (1988, 1990) have investigated the ecology of macrobenthos in a tidal creek and adjoining mangroves in West Bengal. Chaudhuri and Chakroborty (1989) investigated the Sunderban mangroves. Mandal and Nandi (1989) studied the fauna of Sunderban Mangrove Ecosystem. Balachandran *et al.* (1989) observed the Chlorophyll a and phaeopigment as indices of biological productivity in the inshore waters of Cochin. Purushan (1989) has given the fishery potential of Kerala mangroves.

Alongi (1990) examined the effect of tidal upwelling of mangrove detritus on sediment nutrient chemistry, Nutrient regeneration and oxygen fluxes in a coastal area of Central Great Barrier reef lagoon. (Basha, 1991) conducted certain amount of research on the vegetation and mapping aspects of mangroves in Kerala Bhosale *et al.* (1991) presented a data on the endangered mangrove areas of Maharashtra. Prabhakaran *et al.* (1990) discussed the soil fungi of Mangalavanam area. Santra (1991) observed the phytoplankton communities in the mangroves of West Bengal region in India. Sivadasan (1991) conducted a study of mangroves and allied species of Mangalavanam. Basha (1992) assessed the status and gave information on the potential mangrove areas in Kerala. Mani (1992) provided the data on Phytoplankton communities of Pichavaram mangrove areas. Rajgopalan (1992) studied the ecological aspects of mangrove ecosystems in a tropical estuary. Chakraborty and Choudhury (1992) again explained the ecological studies on the zonation of Brachyuran crabs in a virgin mangrove island of Sunderbans. Chakraborti (1993) cited the biodiversity aspects of the Mangrove ecosystem of Sunderban. Sunil kumar (1993) studied the macrobenthos of various mangrove environments in

Kerala. Pandit *et al.* (1994) reported about the threatened fishes and their occurrence in Sunderban areas. Ingole *et al.* (1994) recorded a new variety of Clam (*Gelonia erosa*) in the west coast of India. Devaraj *et al.* (1994) gave a brief account about the vulnerable ichthyofauna from South Indian estuarine mangrove system. Selvaraj (1994) studied the influence of mangrove on the biological resources and fishery of Kakinada. Deshmukh and Balaji (1994) discussed genetic resources conservation of mangrove forest areas. Jayson (1994) reported that avian species richness at Mangalavanam was high during the summer months.

Sivadasan *et al.* (1995) observed the photosynthetic pigments of benthic microflora in the mangroves associated with Cochin estuary and stated that Chlorophyll a of benthic flora values were ranging between 57.26 $mg.m^{-2}$ (Postmonsoon) to 78.36 $mg.\ m^{-2}$ (premonsoon). Kathiresan *et al.* (1995) explained a new variety of mangrove vegetation in the Pichavaram mangrove zone. Gopinathan and Selvaraj (1996) studied the importance, conservation and management of mangrove ecosystem. The birds account of various mangroves in Kerala studied by various researchers such as Kurup (1996); NEST (1993); Mohandas *et al.* (1994)). Sheeba *et al.* (1996) stated that Cochin backwaters receive amble input of phosphorus through the effluent from fertilizer factory. Foote *et al.* (1996) discussed the process of wetland loss in India and the measures to be adopted for environmental conservation. Unni and Kumar (1997) reported that 17 true mangrove species and 223 semi mangrove species occur in Kerala. During 1997, Kjerfve *et al.* (1997) under UNESCO published articles on Mangrove ecosystems of Latin America and Africa, and explained the impacts of various climatic conditions on mangrove environment. Panitz (1997) discussed the ecological description of the Brazil mangroves and covered micro and macro fauna and their nutrient relationship. Vanini *et al.* (1997) observed a typical arboreal phenomenon of true mangrove crab-*Sesarma spp.* Baharudeen (1997) analyzed sediment characteristics of different mangrove systems around Kerala. Filho *et al.* (1997) studied the distribution and diversity of Bracyuran crabs in Guanabra bay, Brazil. Prince Jeyaseelan (1998) presented a manual on fish eggs and larvae from Asian mangrove waters, Published by UNESCO. Nirmala (1999) conducted observations on microbio-chemical production and consumption of oxygen in the estuarine waters of Mangalavanam. Jayson (1999) gave an account on the bird's of Mangalavanam and clearly

mentioned that Mangalavanam qualifies the criteria for declaring it as an International Bird Area (IBA) due to the presence of more than 1500 little cormorant and the presence of more than 1000 Black crowned Night heron, which form one percent of the total population. Selvaraj (2000) documented ecological studies on Kerala mangrove systems. The present work is an effort on general ecological condition prevailing in the Mangalavanam mangrove ecosystem and their impacts over the biodiversity during the year 2002.

3.MATERIALS AND METHODS

3. MATERIALS AND METHODS

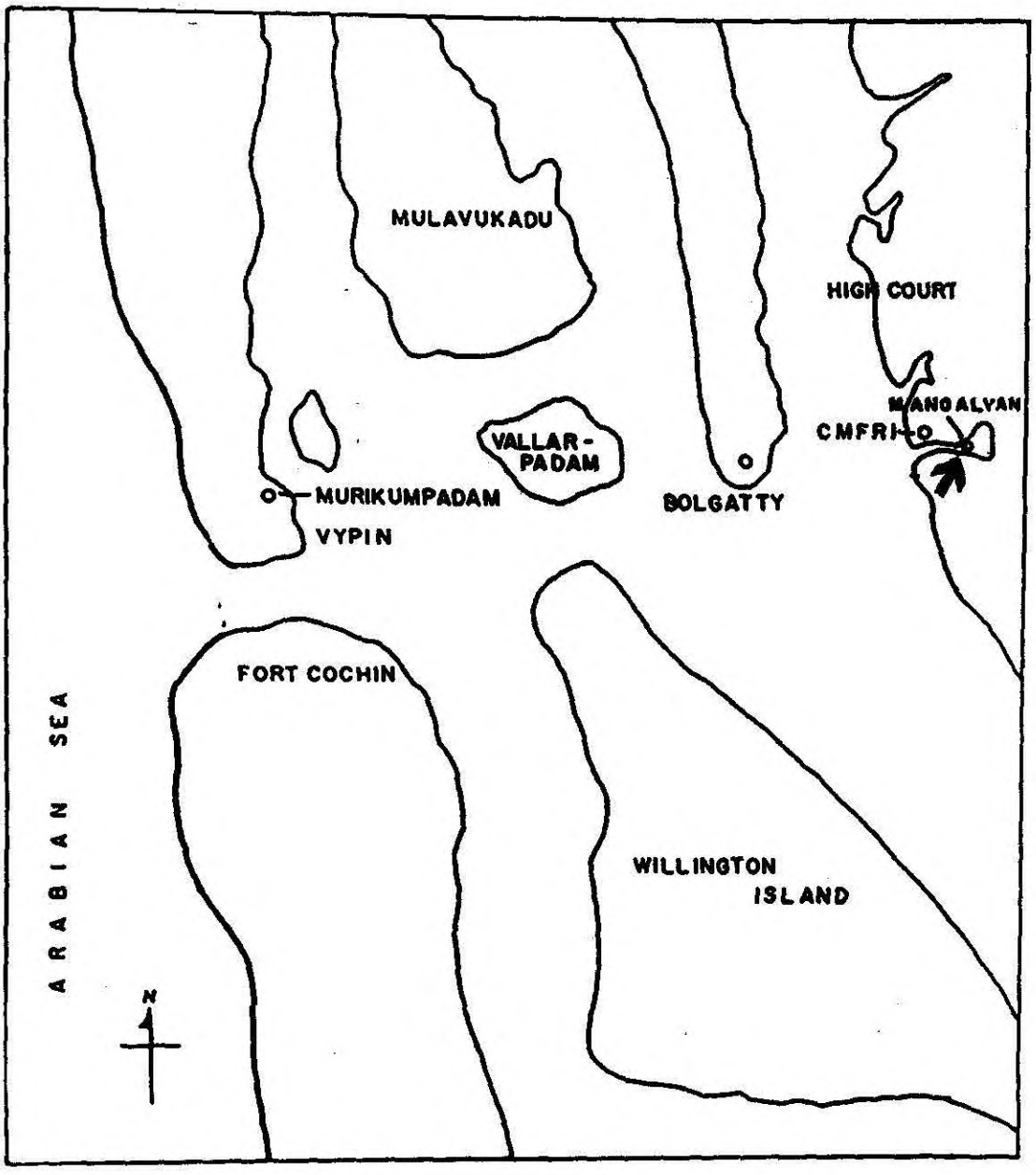
3.1. Topography

Mangalavanam an ecologically sensitive mangrove ecosystem is located at $9^0$00'59" and 76^0 01'11" and almost in the northern fringes of Cochin City. The mangrove is having direct connection with Vembanad backwaters by a 10 feet width canal, which is more or less functioning as a feeder channel to the ecosystem. While the mangrove is protected by the high compound walls of Hindustan petroleum on the northern and eastern sides, Ernakulam Railway goods station is located in the Southern side and the western boundary is Salim Ali public road passing in front of Central Marine Fisheries Research Institute Cochin. The total Area is approximately 8.44 ha. During high tide the water enters into the mangrove and mudflats expose at low tide and as such regular submergence and emergence of land mass takes place in the area. In the middle of the lake, there is a small island with dense mangrove vegetation. It has been declared as a bird sanctuary in the name of former ornithologist 'Salim Ali' and directly under the control of Kerala Forest Department. Although mangrove is occupied by rich avian fauna, anthropogenic activities have adversely affected the general biota of the ecosystem. Sampling stations were selected according to the topography and morphology of the area. In order to get the information requires for the present study samples were collected uniformly every month for a period of 6 months from January to June 2002.

3.2. Sample Collection

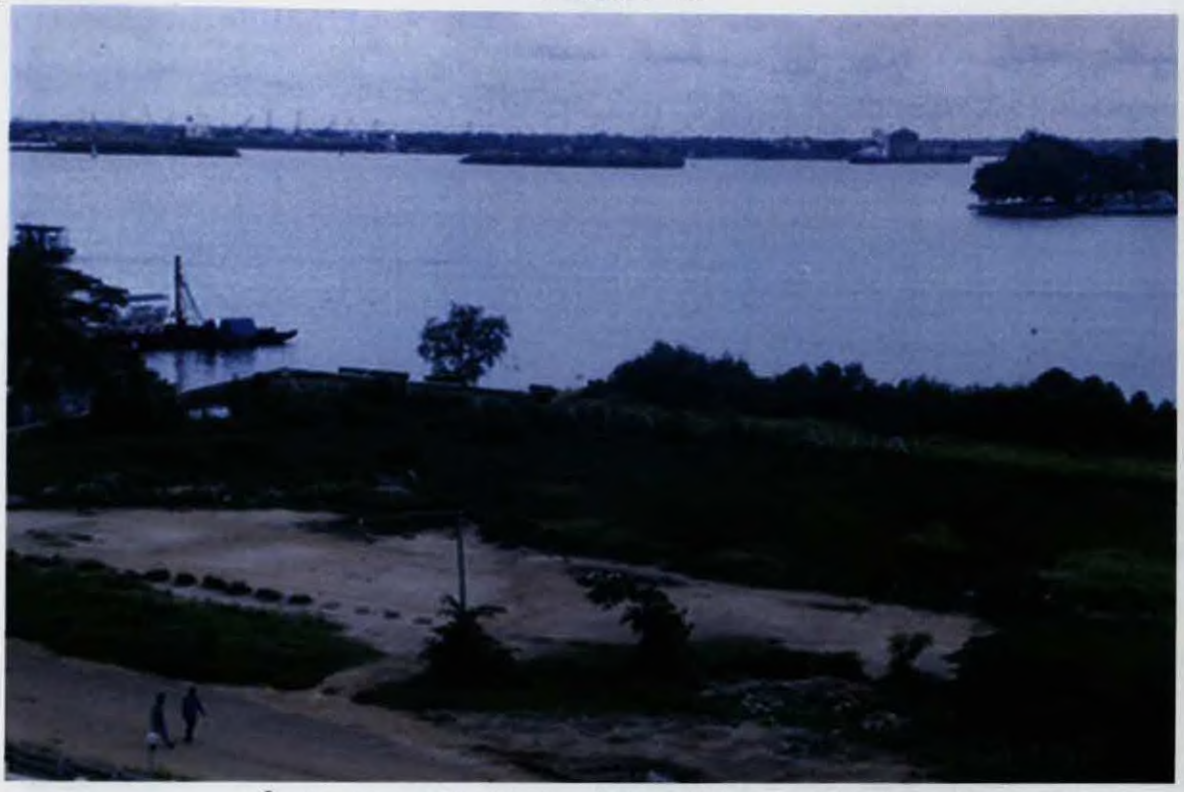
First sampling station is situated in the mouth of the canal at the backwater while the second sampling station is located in the middle of the canal proper. The third and fourth sampling stations were fixed in the north and southeast area of the mangrove respectively. In situ observations were done on temperature by an ordinary thermometer graduated up to 40^0c and salinity has been measured by refracto salinometer. Other conservative and non-conservative parameters were estimated as per the method described in American Public Health Association – APHA (1981). The water samples were collected in plastic containers while samples for oxygen had been taken in the winkler bottles. The soil / sediment samples were

PLATE - I



Cochin backwaters showing the Mangalavanam Mangrove.
(Not drawn to scale)

PLATE - II



A. Station-1 At the begining of the feeder channel from Vembanad backwater to the mangrove.

B. Station - 2 At the middle part of the feeder channel - human intervention causing cultural eutrophication.

PLATE -III

A. Station-3 Emergence of terrestrial vegitation - an indication of anthropogenic intervention

B. Station-3 Photograph shows, the isolated *Avicennia* trees-Deforestation and shrinking of the mangroves.

PLATE - IV

A. Station -4 With in the mangrove on the north west region view during high tide

B. A favourable Avian niche of Mangalavanam mangrove.

collected by utilizing Von Veen grab, covering an area of 0.038m^2.This grab was used for collecting benthos samples from the stations in the mangroves. The results were recorded as biomass per square meter.

3.3. Methodolgy

3.3.1. Macrobenthos

The organisms were separated from sediment by the 500micron sieve. The macro benthic fauna retained by the meshes, which had been fixed in formalin and later stained in rosebengal for further enumeration of infauna.

3.3.2. Plankton

Plankton samples were collected by using plankton net made of bolting silk cloth No21.Plankton samples for phyto and zoo were collected separately and fixed in 5% formalin for further qualitative and quantitative estimation, which had been done in the laboratory. Samples were allowed to settle for 24hrs in a measuring cylinder. After all the particulate matter settled down to the bottom, the supernatant was carefully siphoned off without disturbing the settled volume. The one litre sample was concentrated to about 60ml and settled volume was noted. Qualitative and quantitative enumerations were done by counting replicate aliquots and the average was noted for estimating the total phytoplankton count per litre in each station. The cell count of different species (n_i) per litre was arrived by the following formula:
Number of phytoplankton per litre of i^{th} species, $n_i = \overline{X_i}\,(v/V)$. Where= $\overline{X_i}$ is the average count of i^{th} species, V the volume (l) of sample and v the volume (ml) to which the sample was reduced.

The total plankton count (N) per litre could be arrived by

$$N = \sum_{i=1}^{s} n_i$$

Scoop-net bucket method is effectively used in mangrove for the collection of zooplankton. The principle is to filter a known quantity of water (minimum 1 m^3 of water which is equal to 100 buckets of water drawn with a bucket of 10 liter capacity) through a scoop net. The scoop net has a ring of 30 cm diameter made of a 12 mm aluminum rod. The ring is made in such a way that the two ends of the rod extend as a handle for holding the net. To the ring is attached a net cone of

75 cm length which tapers towards the cod end. Since 100 % water filtration is assured through the net even bolting silk can be used as the net fabric, which will ensure capture of even the smallest larval forms. Zooplankton were estimated by *sedgewick rafter cell.*

3.3.3. Fish

Finfish and shellfish samples were collected from the local fishermen and only qualitative estimation has been done.

3.3.4. Macro vegetation

The mangrove vegetation had been identified up to species level. The epifauna has also been included in the present investigations.

3.3.5. Sediment sample analysis

3.3.5.1.Wet sample

A) pH

The pH of the sediment samples was determined on the same day in the laboratory by using an ECIL pH meter (model pH 5652).The pH meter was calibrated initially and the accurate probe measurements were recorded.

B) Nitrite-Nitrogen

Initially the nitrogen was extracted by 2M potassium chloride digestion method in a laboratory shaker (Hesse, 1971). Then the No_2-N in the sediment was determined by spectrophotometrically according to Strickland and Parsons (1968).

C) Nitrate-Nitrogen

As per the method specified by Hesse, 1971 the digested sample is allowed for reduction in a period of 20hrs.Then the No_3-N is estimated by Wood *et al.*, 1967.

D) Ammonia

The sediment ammonia determined by phenol hypochlorite method as per Zolarano (1969) from the extracted solution.

3.3.5.2. Dry sample

A) Organic carbon

The organic carbon of the sediment is estimated by Walkley and Black's titration method as described by Jackson (1958).

B) Available Phosphorus

The phosphorus in the sediment is assessed by Olsen's method with prior extraction using 0.5M sodium bicarbonate described by (Jackson, 1958).

C) Available potassium

Available potassium of the sediment sample was estimated by Ammonium acetate extraction. Ten gram oven dried, ground sample was allowed for extraction with 100ml of 1N neutral Ammonium acetate in a 250 ml Erlenmeyerflask for a period half an hour in a electric shaker. The solution was then filtered through whatman filter paper No.1 and the filtrate was taken for determining the available potassium with the help of Chemito digital flame photometer (Jackson, 1958).

3.3.6. Water sample

A) Dissolved Oxygen

The dissolved oxygen of the sample was estimated by Winkler method (1988). The estimations were done in the laboratory after fixing the sample with winkler A and winkler B solutions at the collection sites itself.

B) Dissolved orthophosphate

Phosphorus in the seawater in the form of dissolved orthophosphate has been determined by Ascorbic acid method according to Murphy & Riley (1962).

C) Reactive Silicate

Silicon present in the dissolved form mainly as the alkali salts of orthosilicic acid $Si(OH)_4$,which was estimated by the method described by Mullin and Riley (1955) and modified by Strickland and Parson (1968).

D) Ammonia

For the determination of ammonia in the method involving indophenol blue reaction is well known and the one followed here is that of Zolerano(1969).

E) Nitrite-N

The Nitrite –N present in the water sample is estimated by the same procedure advocated by Mullin and Riley (1963) excluding the cadmium column reduction process.

F) Nitrate-N

The estimation of Nitrate is based on a method by Morris and Riley (1963) with some modifications suggested by Grasshoff (1964) and Wood *et.al.* (1967).

G) Chlorophyll pigments

Chlorophyll bearing organisms present in known volume of water sample was filtered and dissolved in a solvent (Acetone 90% v/v). The pigment content dissolved in unit volume of acetone was measured spectrophotometer according to Parsons, Yoshiaki Maita and Carol Lalli,(1984).

H) Transparency

Transparency of the water was measured by using Secchidisc, specified by (Boyd, 1992).

3.3.7. Statistical Analysis

The results were statistically analyzed to obtain diversity indices, richness indices and evenness of phytoplankton and zooplankton separately. ANOVA test was carried out to analyze the significant variation of ecological parameters during the period of investigation and between the months. The diversity indices, richness indices and evenness indices were calculated according to Ludwig and Reynolds (1988) and details are as follows:

Diversity is composed of two components, which are richness and evenness. Richness expresses the total number of species present and evenness emphasizes how the abundance data are distributed among species.

The present study aims to obtain the distributional pattern, abundance and total population groups and as a result diversity of each group.

Richness Indices

Two historically well-known richness indices are as follows: Index 1, the Margalef (1958) index,

$$R1 = \frac{S-1}{Ln(n)}$$

Where 'S', the total number of species and 'n' the total number of individuals observed.

And Index 2, the Menhinick (1964) index

$$R2 = \frac{S}{\sqrt{n}}$$

Here R2 as an *index of richness* is more valuable where a functional relationship between S and n of the form $S=K\sqrt{n}$ exists, where K is a constant.

Peet (1974) termed diversity indices as heterogeneity indices as diversity indices incorporate with richness and Evenness.

Diversity Indices

Simpson (1949) index

$$\lambda = \sum_{i=1}^{s} \frac{ni\,(ni-1)}{n\,(n-1)}$$

Where 'S' Number of species, 'ni' number of individuals belongs to the individuals and 'n' total number of individual in the particular period. 'λ' varies from 0 to 1 and gives the probability that two individuals drawn at random from a population belong to the same species. If the probability is high that both individuals belong to the same species, then the diversity of the sample is low.

Shanon's index H' is widely used in diversity index. It measures the average uncertainty in predicting to what species an individual chosen will belong. Uncertainty increases as the number of species increases.

$$\text{Shanon's index } H' = -\sum_{i=1}^{S^*} pi \ln (pi)$$

Where H' is the average uncertainty per species S*, the total species and pi, are proportional abundance. We can arrive the Hill's diversity numbers with these diversity measures. Those are

N0 = S where S is the total number of species and N0 is the number of all species in the sample regardless of their abundance.

$N1 = e^{H'}$, where H' is the Shanon's index and N1 measures the number of abundant species in the sample.

N2 = 1/λ, where λ is the Simpson's index and N2 measures very abundant species in the sample.

Evenness Indices

$$E1 = \frac{H'}{Ln(S)} \quad \text{(J' of Pielou, 1975, 1977)}$$

$$E2 = \frac{e^{H'}}{S} \quad \text{(Sheldon, 1969)}$$

$$E3 = \frac{e^{H'}-1}{S-1} \quad \text{(Heip, 1974)}$$

$$E4 = \frac{1/\lambda}{e^{H'}} \quad \text{(Hill, 1973)}$$

$$E5 = \frac{1/\lambda - 1}{e^{H'}-1} \quad \text{(Hill, 1973)}$$

E2, E3 and E1 are sensitive to species richness and E4&E5 relatively unaffected by species richness.

4. RESULTS

4.Results

Sampling Procedure

The regular data collection was done once in a month from various stations connected with the mangrove system from January to June 2002.

4.1. Ecological Parameters

4.1.1.Water temperature

The temperature regime of the four sampling stations is represented in Figure-1. Temperature values differ significantly among the stations ($P<0.05$), are illustrated in Table-35. In Station-1, the average water temperature during the study period was 30^0 C, while the temperature ranged from 28^0 C to 33^0 C during March and April respectively. The gradual fluctuation in Sampling Station-2 was observed and a mean temperature noted was 29.5^0 C (Table-2). The minimum temperature of 28^0 C was recorded in February and March, while a maximum of 31^0 C was observed in January. A similar trend was also noticed in Station-3; where as the lowest temperature of 27^0 C was recorded in February and May (Table-3). The highest temperature of 29^0 C was observed in January and April. The mean value of temperature 29^0 C was observed in Station-4 (Table-4), where it ranged from the minimum of 28^0 C in January and to the maximum of 30^0 C obtained in March and April months.

4.1.2. pH

pH profile of the sampling stations are shown in Table-1. The values didn't exhibit any significant difference among the stations ($P>0.05$), emphasized in Table-35. An average pH value of 7.6 was recorded in Station-1, while the values ranged from 7.1 to 8. The maximum value was recorded in January and the minimum in February. Similar trend had been exhibited in the sampling Station-2, where those values ranged from 7.26 and 8 (Table-2). The pH values recorded a maximum concentration of 7.6 in January and a minimum of 7 in June observed in the Station-3 (Table-3). Very little fluctuations were noted in the sampling Station-4, where the pH

Parameters	January	February	March	April	May	June
Temperature	30	32	28	33	29	30
pH	8	7.1	7.2	7.56	7.41	7.37
Salinity (ppt)	20	21	20	22.8	20	21
Dissolved Oxygen (ml/l)	3.4	3.687	3.72	3.625	3.41	3.8
Ammonia (μg at/l)	1.142	2.892	1.136	2.5677	1.872	1.17
Nitrite-N (μg at/l)	0.0226	0.0342	0.022	0.023	0.027	0.0301
Nitrate-N (μg at/l)	0	0	0	0.1159	0	0.97
Phosphate (μg at/l)	1.372	2.89	0.982	0.783	1.12	1.01
Silicate (μg at/l)	32.1	41.6	56.483	49.185	52.31	41
Chlorophyll a (mg/m^3)	1.214	1.2693	1.2301	1.2412	1.2971	1.212
Chlorophyll b (mg/m^3)	0.002	0	0	0.001992	0.00136	0
Chlorophyll c (mg/m^3)	0.113	0.104	0.142	0.1272	0.1034	0.1012
Transparency (cm)	71	62	59	59	57	56

Table-1. Station parameters

Parameters	January	February	March	April	May	June
Temperature	31	28	28	30	29	30
pH	8	7.26	7.3	7.56	7.29	7.3
Salinity (ppt)	16	14	15	16.5	15.5	16
Dissolved Oxygen (ml/l)	4.2	3.8	3.4	3.74	4	3.8
Ammonia (μg at/l)	2.84	3.3	3.012	3.1	2.98	2.1
Nitrite-N (μg at/l)	0.015	0.0475	0.0237	0.05	0.039	0.0271
Nitrate-N (μg at/l)	0	0.0048	0.3249	0.048	0.296	0.032
Phosphate (μg at/l)	2.698	4.024	2.195	3.1	2.61	2.2
Silicate (μg at/l)	43.2	39.26	67.72	63.78	62.31	59.31
Chlorophyll a (mg/m^3)	0.8233	1.211	1.1982	1.282	1.270	1.243
Chlorophyll b (mg/m^3)	0.002143	0.00192	0	0	0.00131	0
Chlorophyll c (mg/m^3)	0.9101	0.009	1.182	0.117	0.193	0.114
Transparency	65	68	67	54	56	58

Table-2.Station 2 water parameters

Parameters	January	February	March	April	May	June
Temperature	29	27	28	29	27	29
pH	7.6	7.13	7.3	7.25	7.19	7
Salinity (ppt)	16	14	15	16.5	15.5	16
Dissolved Oxygen (ml/l)	3.9	3.42	3	3.25	3.19	3.7
Ammonia (μg at/l)	8.372	6.749	7.312	2.45	5.13	6.27
Nitrite-N (μg at/l)	0	0.057	0.0842	0.462	0.137	0.096
Nitrate-N (μg at/l)	0	0	0.1255	1.1996	1.0172	0
Phosphate (μg at/l)	45	38	40	47.148	41	43.1
Silicate (μg at/l)	19.12	36.19	56.19	68.3	49.58	62
Chlorophyll a (mg/m^3)	1.482	1.33	2.582	2.598	2.599	2.61
Chlorophyll b (mg/m^3)	0.01718	0.00123	0.000614	0	0	0.0014
Chlorophyll c (mg/m^3)	0.214	0.197	0.2614	0.314	0.293	0.301
Transparency (cm)	60	57	57	58	62	59

Table-3. Station 3 water parameters

Parameters	January	February	March	April	May	June
Temperature	28	28	30	30	29	30
pH	7.43	7.5	7.32	7.48	7.5	7.2
Salinity (ppt)	15	14	13	14.5	14.5	14
Dissolved Oxygen (ml/l)	3.6	3.3	3.1	3.254	3.613	3.4
Ammonia (μg at/l)	3.3412	5.0123	4.6329	5.78	5.141	4.921
Nitrite-N (μg at/l)	0.02	0.0665	0	0.044	0.0587	0.062
Nitrate-N (μg at/l)	0.01	0.0038	0.002	0.12605	0.1983	0.142
Phosphate (μg at/l)	21.4	30.39	20.9	17.36	27.81	30
Silicate (μg at/l)	19.27	29.77	20.312	74.872	47.81	46.24
Chlorophyll a (mg/m^3)	1.810	1.31	2.389	2.401	2.501	2.31
Chlorophyll b (mg/m^3)	0.00678	0.00101	0.004530	0	0.000128	0.0012
Chlorophyll c (mg/m^3)	0.202	0.110	0.089	0.337	0.314	0.376
Transparency	69	61	63	60	64	61

Table-4. Station 4 water Parameters.

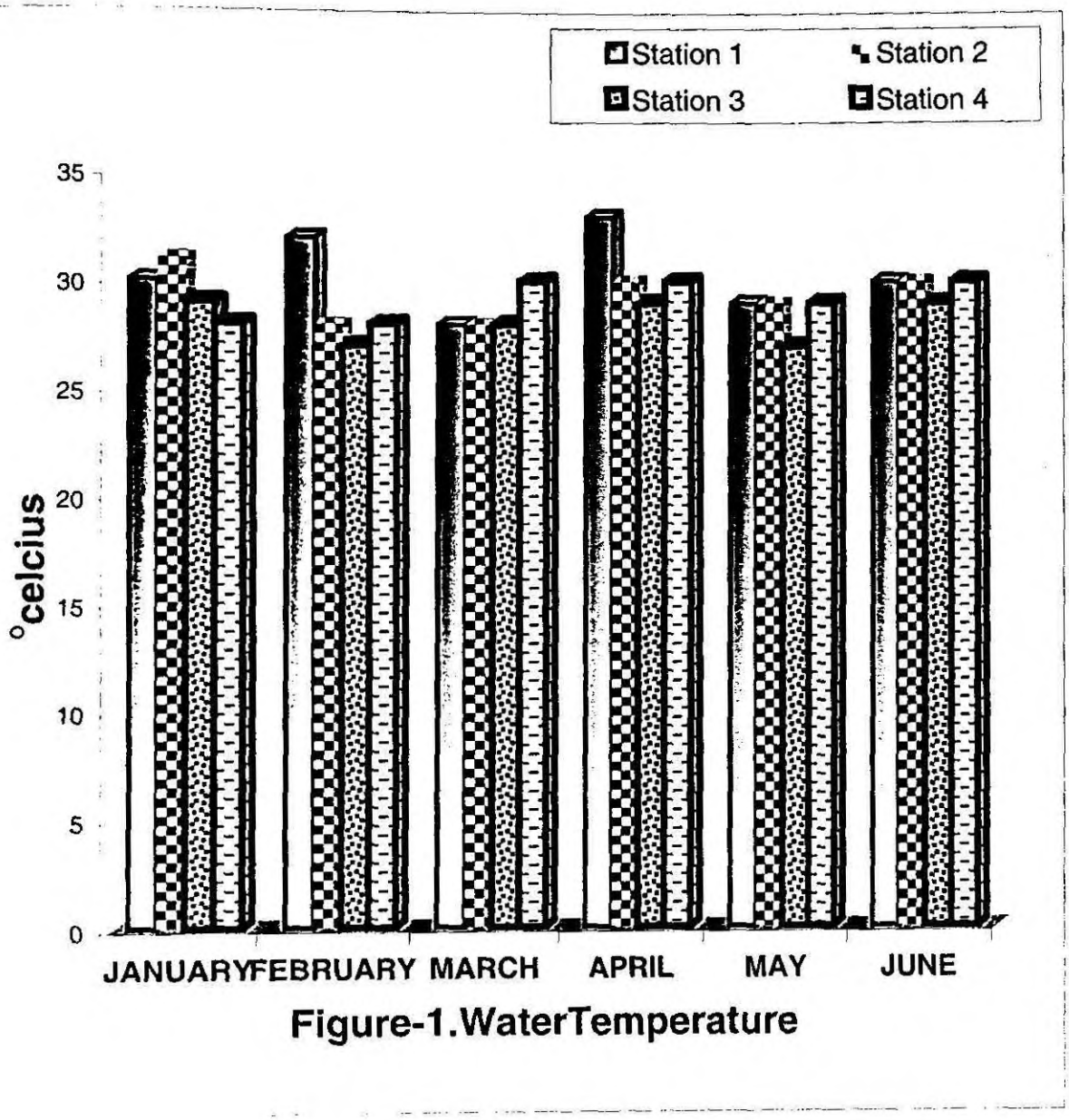


Figure-1.WaterTemperature

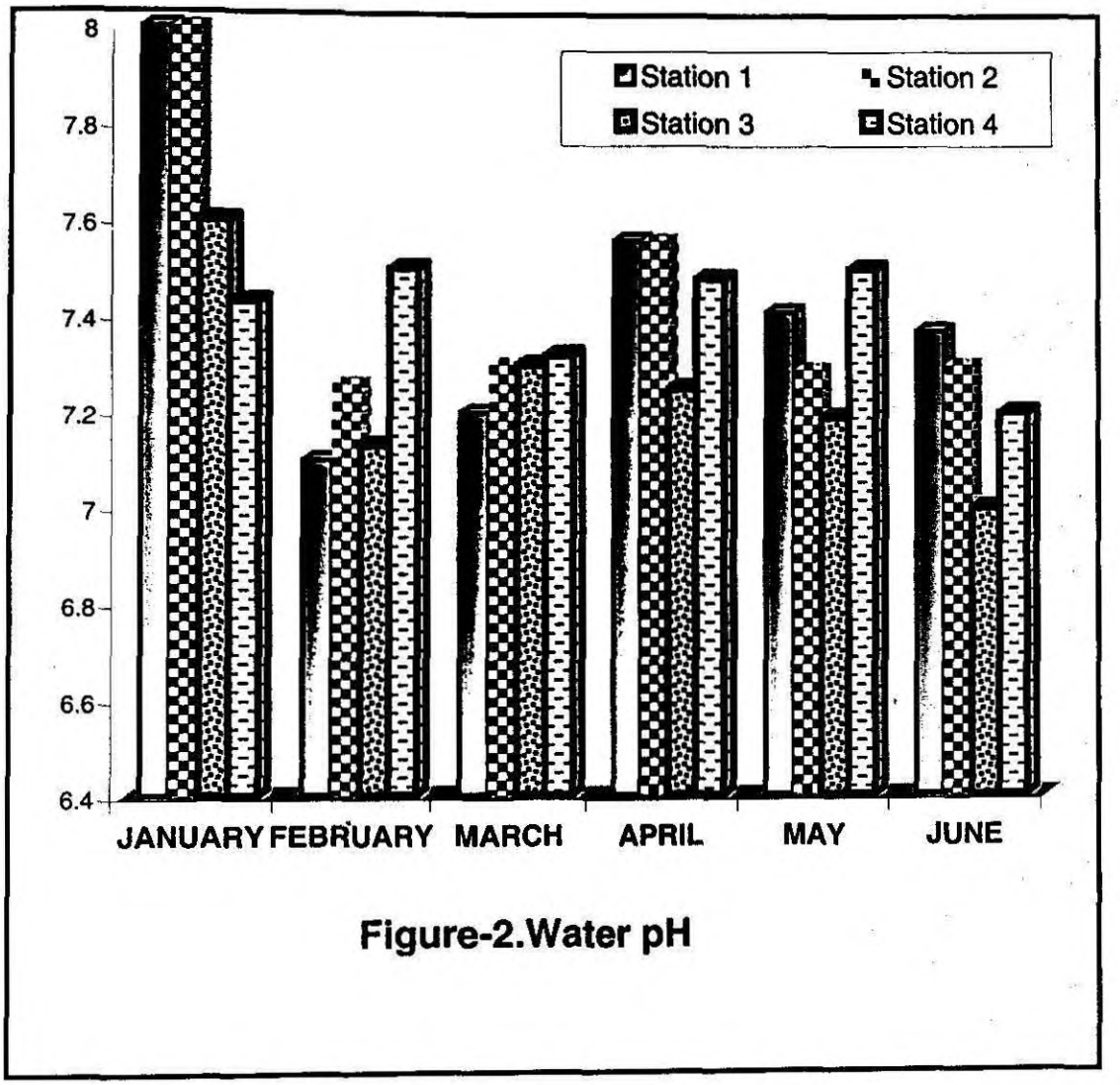


Figure-2.Water pH

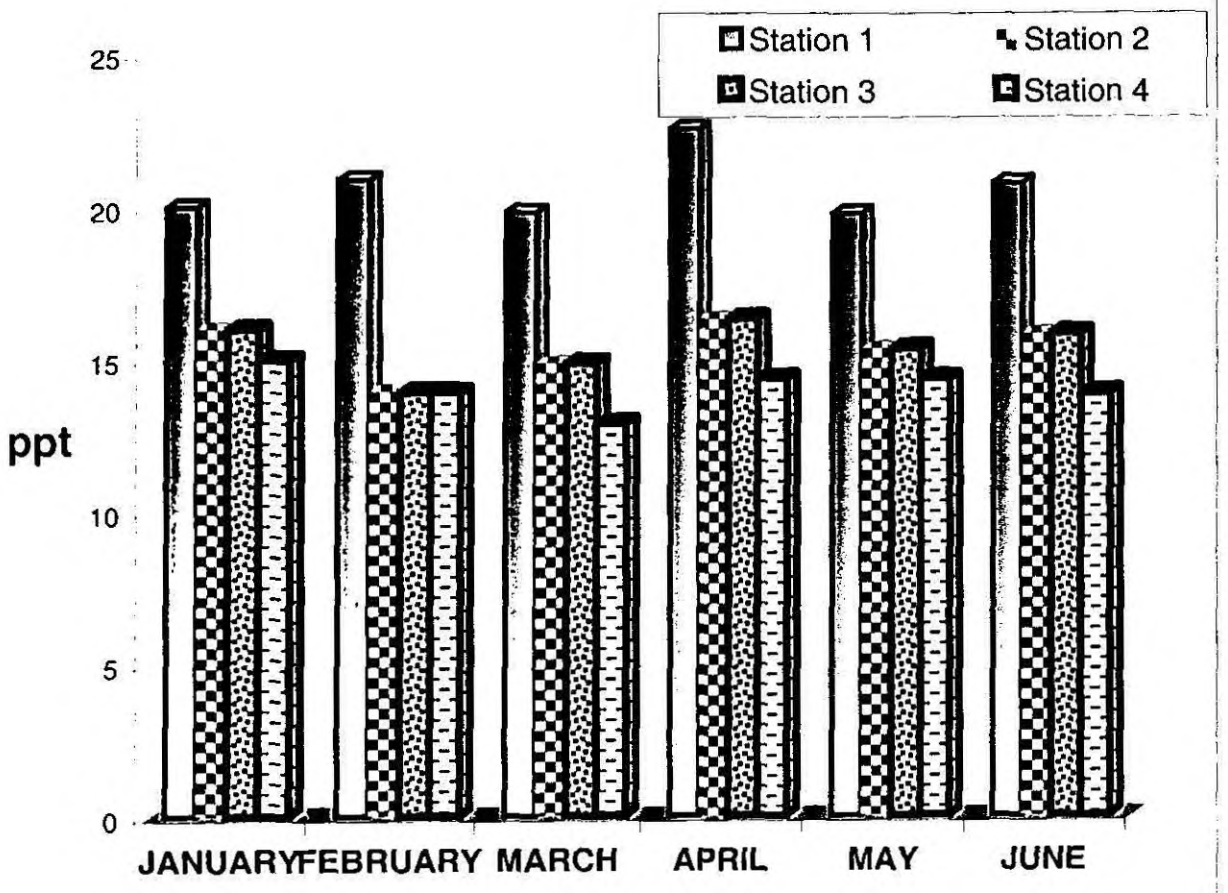


Figure- 3. Water salinity

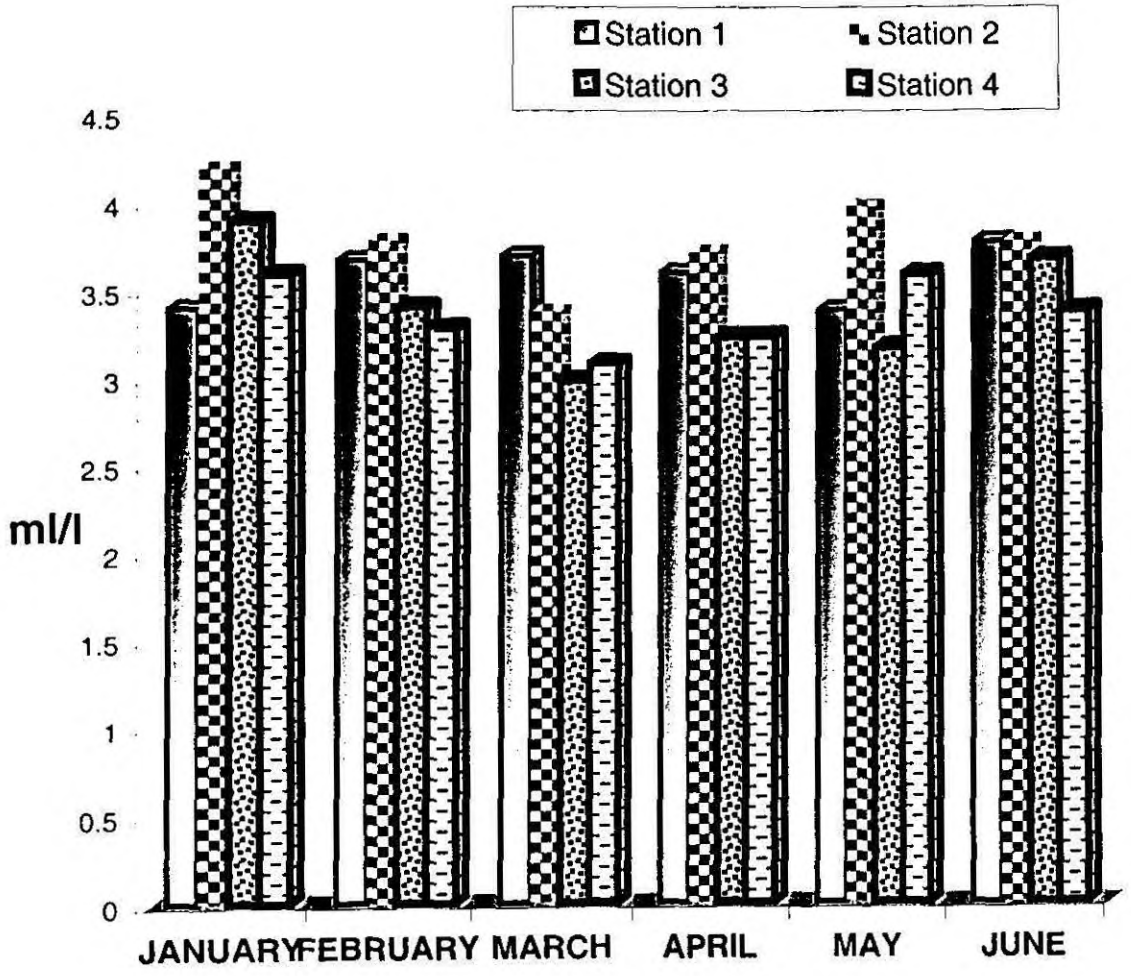


Figure-4.Dissolved Oxygen

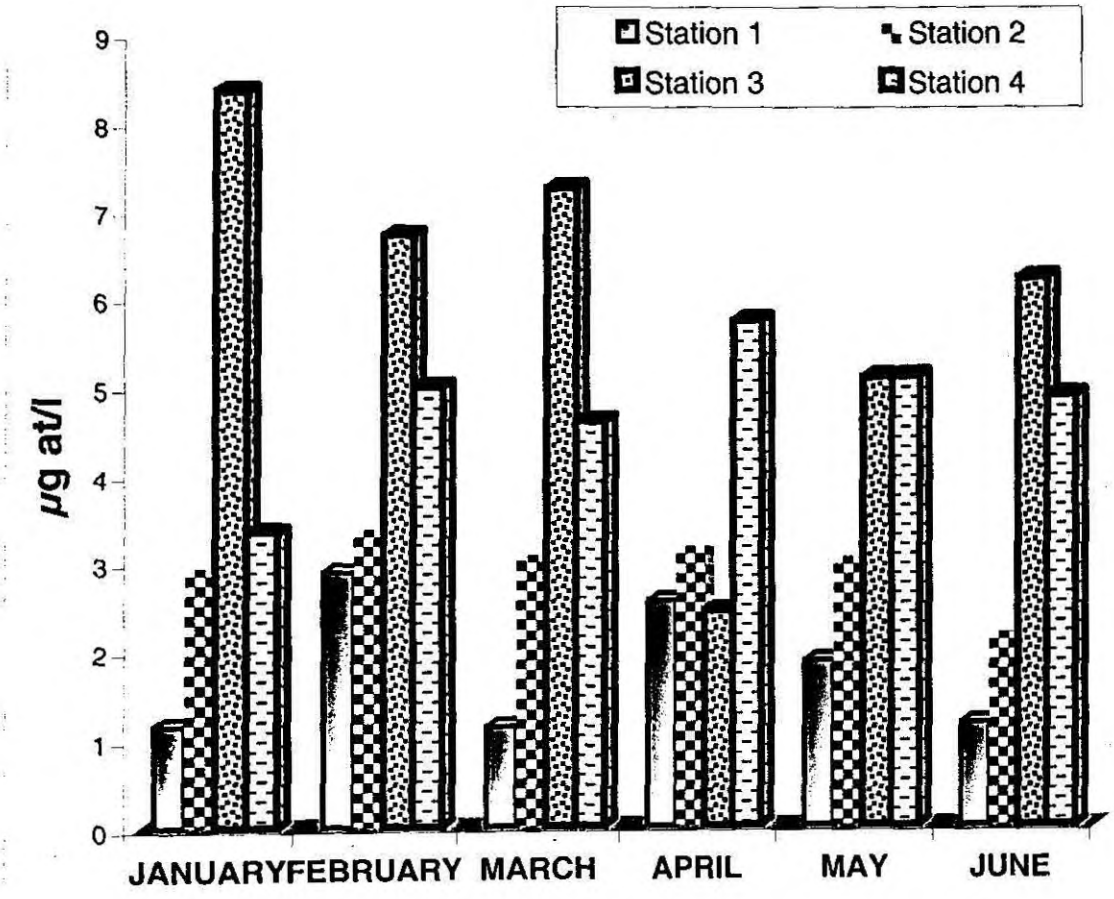


Figure-5.Ammonia

profile ranged from the minimum concentration of 7.2 and maximum of 7.5 during June and May respectively (Table-4).

4.1.3. Salinity

Salinity regimes of the sampling stations are represented in Figure-3. Salinity regime exhibited significant difference among the stations ($P<0.05$), which is showed in the Table-35. Comparatively very low values recorded in Station-4, where a minimum value of 13ppt was noticed in March and a maximum value observed in Station-1 during April. The minimum value of 20ppt was recorded in March and May at Station-1 (Table-1), where the salinity values varied in between 22.8ppt and 20ppt (Table-1). The mean value of 19ppt was observed in Station-2, where the sharp increase in salinity was noticed in June (Table-2). In sampling Station-3 gradual variations observed with the moderate concentrations in between 15 and 16.5ppt recorded in March and April respectively. Generally very low values were noted in the Station-4 and the mean value was 14ppt.

4.1.4. Dissolved oxygen

Dissolved oxygen content of the various stations are exhibited in the Figure-4 and the values showed a significant difference among the stations $P<0.05$ (Table-35). Comparatively highest value was recorded in Station-2, where the values ranged from 3.4 ml/l in March to 4.2ml/l in January (Table-2). Lowest value of 3ml/l was obtained in Station-3 during March and 3.9ml/l was noted in January, which is the maximum at this particular Station during the study period (Table-3). Generally the dissolved oxygen values ranged from 3.1 ml/l to 3.6 ml/l in Station-4 (Table-4). Very low fluctuations had been recorded with in the stations. During March sudden decline in the DO level was observed in all the stations. The mean values were 3.5ml/l, 3.7ml/l, 3.4ml/l and 3.3ml/l in Station-1, 2, 3 & 4 respectively.

4.1.5. Ammonia

Ammonia readings of the four stations are illustrated in Figure-5, while the values didn't show any significant variations among the stations ($P<0.05$) Table-35. Comparatively the peak ammonia readings were often associated with Station-3, where a highest value of 8.372-μg atom/l was observed in January and the least

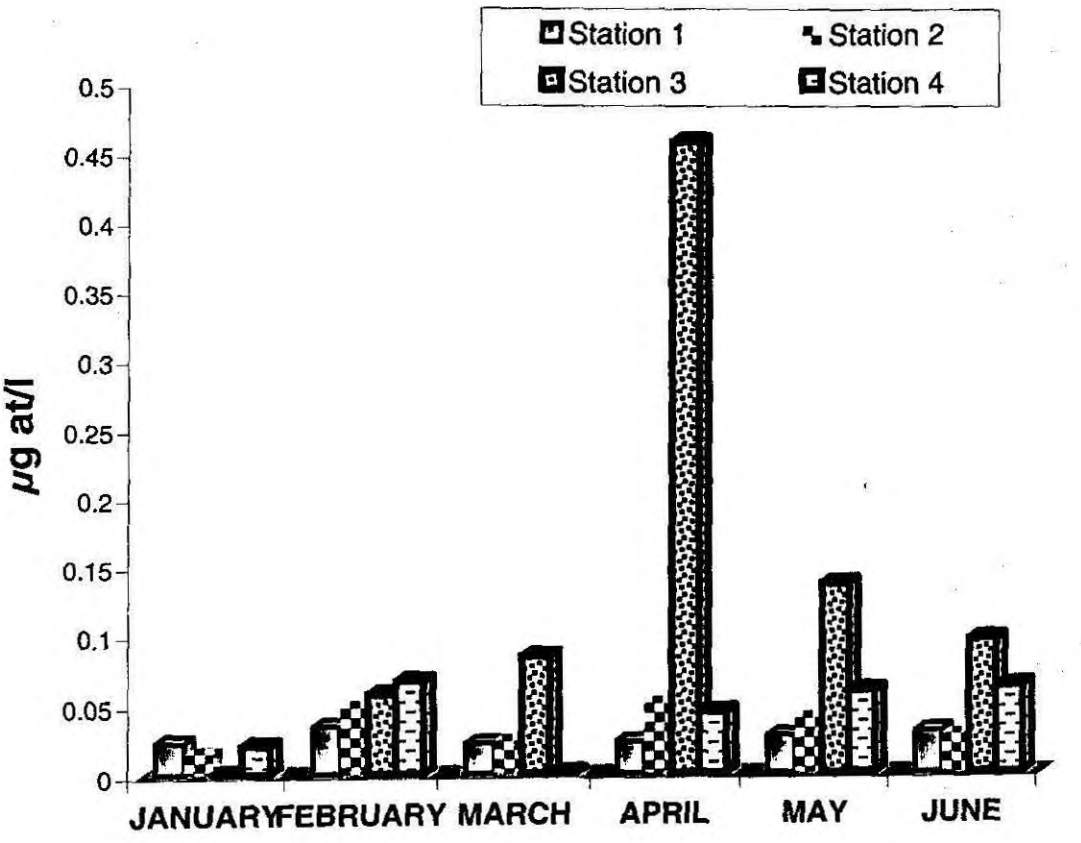


Figure-6.Nitrite-N

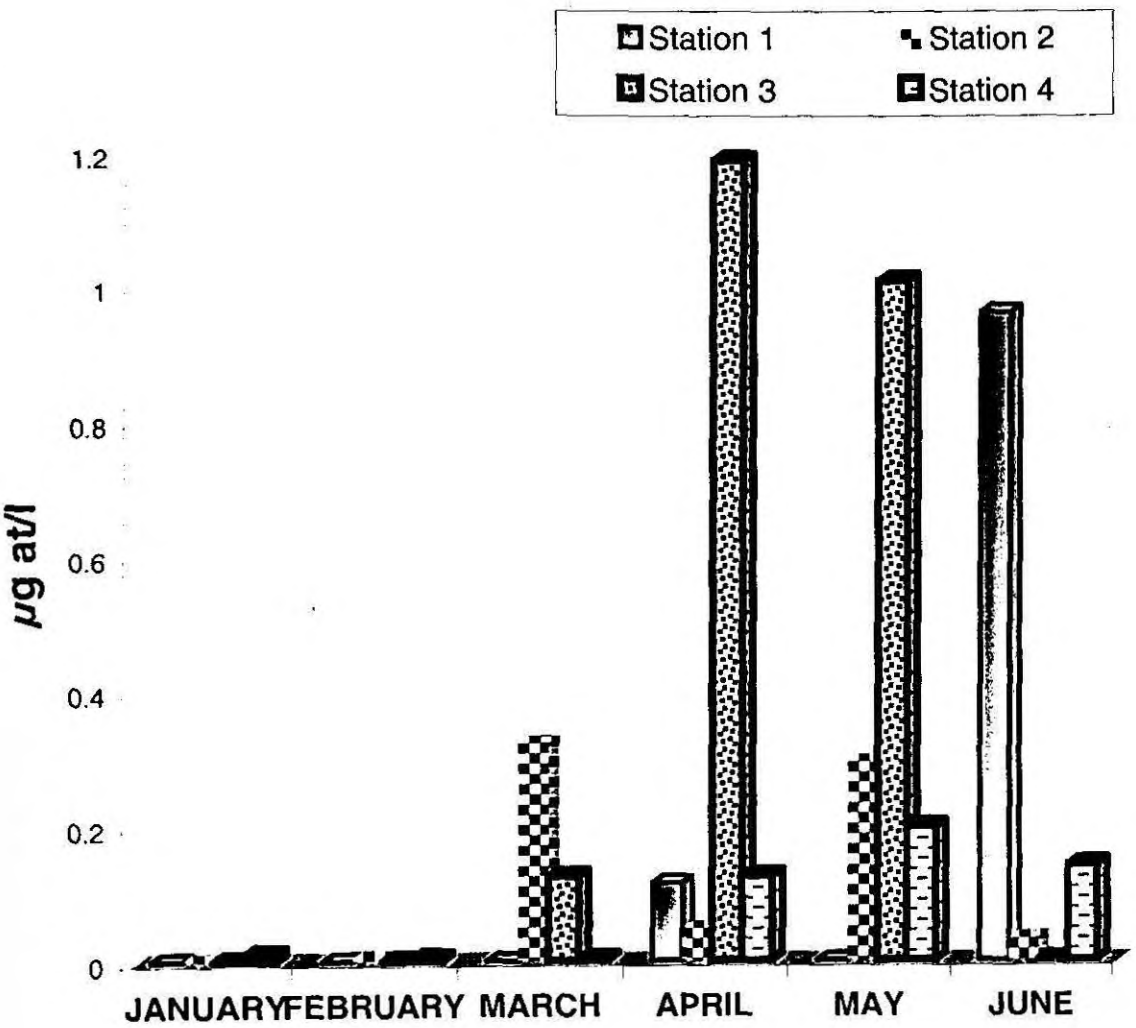


Figure-7.NitrateN

values exhibited in Station-1(Table-1). The ammonia concentrations of Station-1 were fluctuating with a minimum of 1.136-μg atom/l in February and a maximum of 2.892-μg atom/l in March. In Station-2, the mean ammonia reading was 2.8-μg atom/l (Table-2) and the values are more or less stable except during June, where a sudden outfall in value of 2.1-μg atom/l was observed. In Station-3, a minute variation in the mean concentration of 6.04-μg atom/l was noticed, while the abrupt deviation was noticed in April with the value of 2.45-μg atom/l (Table-3). In Station-4, a maximum of 5.78 and a minimum of 3.34-μg atom/l were recorded in April and January respectively (Table-4). Mild fluctuation follows in the concentration during the study period with a mean value of 4.804-μg atom/l.

4.1.6. Nitrite- N

Nitrite values of the various stations connected with the area under investigations represented in the Figure-6 and the values didn't show any significant difference among the stations P>0.05, (Table-35). Nitrite values in Station-1 were ranging from the minimum of 0.022- μg atom/l and a maximum of 0.0342-μg atom/l concentrations in March and February respectively. The nitrite values exhibited a very little fluctuations during the study period. In Station-2, the average nitrite concentration of 0.0337-μg atom/l was noticed with considerable variations ranging from 0.015 to 0.0475-μg atom/l in January and February (Table-2). Generally among four stations the highest value of 0.462-μg atom/l was obtained in Station-3 during April, where the mean concentration was 0.13-μg atom/l and the nitrite was absent in January (Table-3). In Station-4, the nitrite concentration ranged from nil value in March to the maximum of 0.0655-μg atom/l in February (Table-4). The average value of 0.042-μg atom/l was observed in this Station.

4.1.7. Nitrate-N

Nitrate concentrations are presented in Figure-7. The NO3-N did not show any significant difference among the Stations (P>0.05), are shown in Table-35. The nitrate values ranged from 0 to 0.97-μg atom/l in Station-1 (Table-1). It was totally absent during January, February, March and May. A maximum value of 0.97-μg atom/l was recorded in June and the reading in April was 0.1159-μg atom/l. Considerable fluctuations exhibited in Station-2 with the values ranging from 0 to

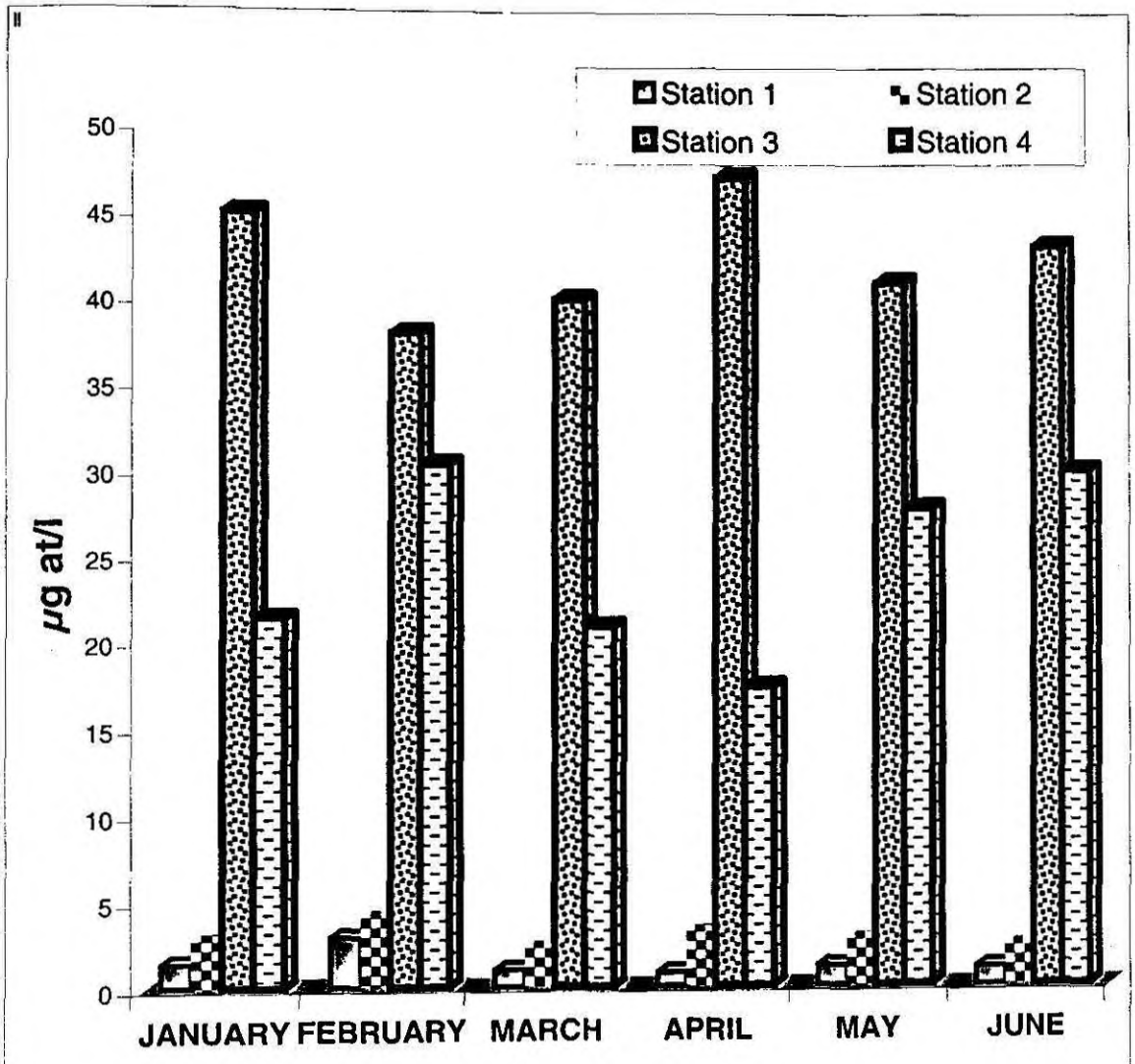


Figure-8.Phosphate

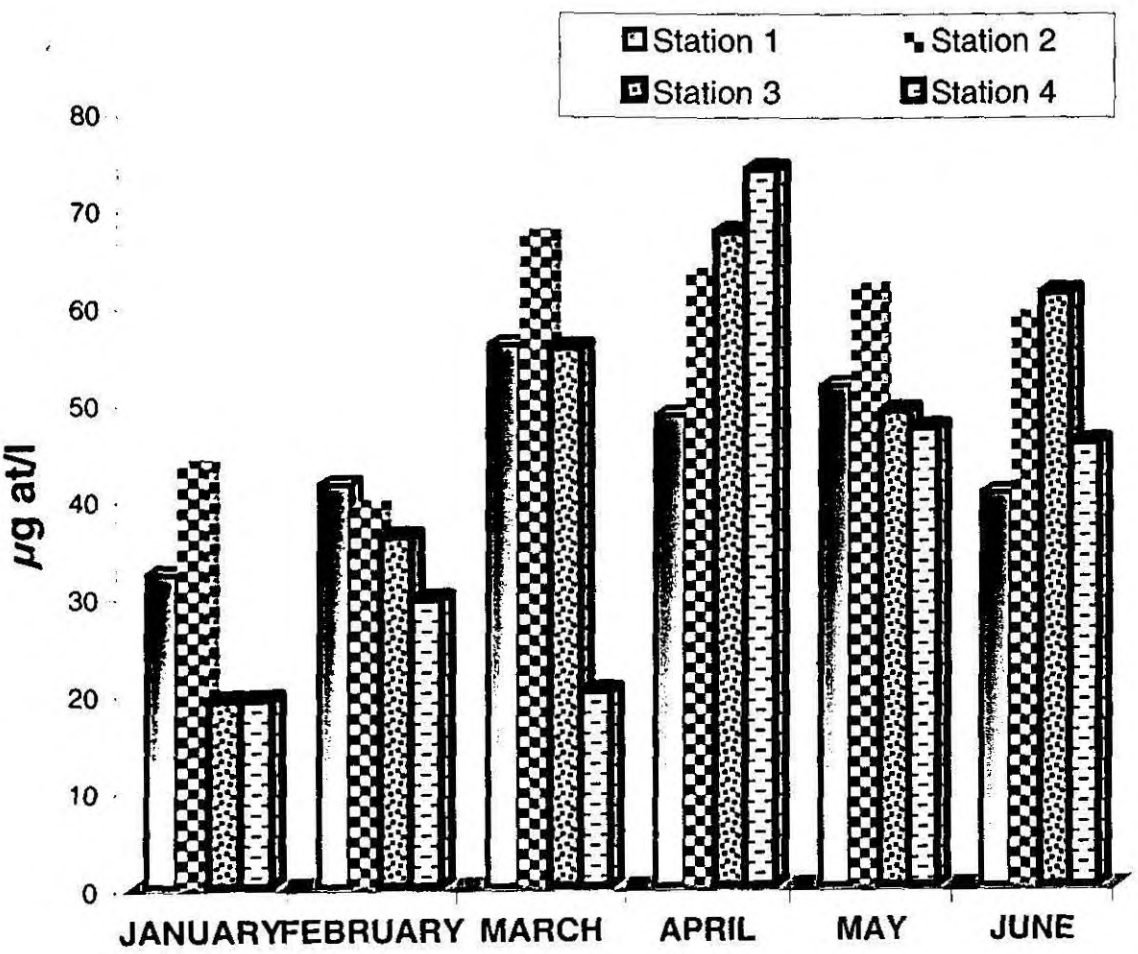


Figure-9.Silicate

0.3249-μg atom/l, where the maximum concentration was in March and a minimum in January (Table-2). Comparatively highest value of 1.1996-μg atom/l was recorded in Station-3 during April, while the readings were fluctuated from nil to 1.1996-μg atom/l (Table-3). NO3-N was absent in January, February and June. The mean nitrate value exhibited in Station-3, was 0.39-μg atom/l. The nitrate readings of Station-4 were fluctuating between the minimum of 0.002-μg atom/l in March and maximum of 0.1983-μg atom/l in May, while the mean concentration was 0.08-μg atom/l (Table-4).

4.1.8. Phosphate:

The fluctuations of phosphate exhibited during various months of all the Stations are illustrated in Figure-8 and significant difference could be observed among the stations ($P<0.05$), are showed in Table-35. The phosphate values were ranging from 0.783 to 47.148-μg atom/l in general. In Station-1, a maximum value of 2.89-μg atom/l in February and a minimum value of 0.783-μg atom/l in April were noticed with a mean value of 1.3595-μg atom/l (Table-1). The phosphate concentrations observed in Station-2, ranged from 2.195-μg atom/l to 4.024-μg atom/l (Table-2). The mean value was 2.8045-μg atom/l. The maximum value was obtained in February and the minimum was in March. The readings in Station-3 were comparatively higher in almost all months and a different pattern was depicted. The nutrient concentrations were higher in January and April with a value of 47.148-μg atom/l in April, while a minimum concentration was 38μg atom/l in February. Station 4 exhibited the highest value of 30.39-μg atom/l in February and a lowest value of 17.36μg atom/l in April. The readings flowed in the mean value was 24.64-μg atom/l in various months during the period of investigation.

4.1.9. Silicate

The silicate concentrations in all four stations are showed in Figure-9, the values didn't vary significantly among the stations ($P>0.05$), in Table-35. The silicate concentrations varied between 32.1-μg atom/l and 56.483μg atom/l in station-1 (Table-1), where the peak was obtained in March and least in January. In Station-2, the peak concentrations were recorded in March, April and May, while the minimum value of 39.26-μg atom/l was recorded in February (Table-2). The maximum concentration of 67.72-μg atom/l was observed in March with the mean

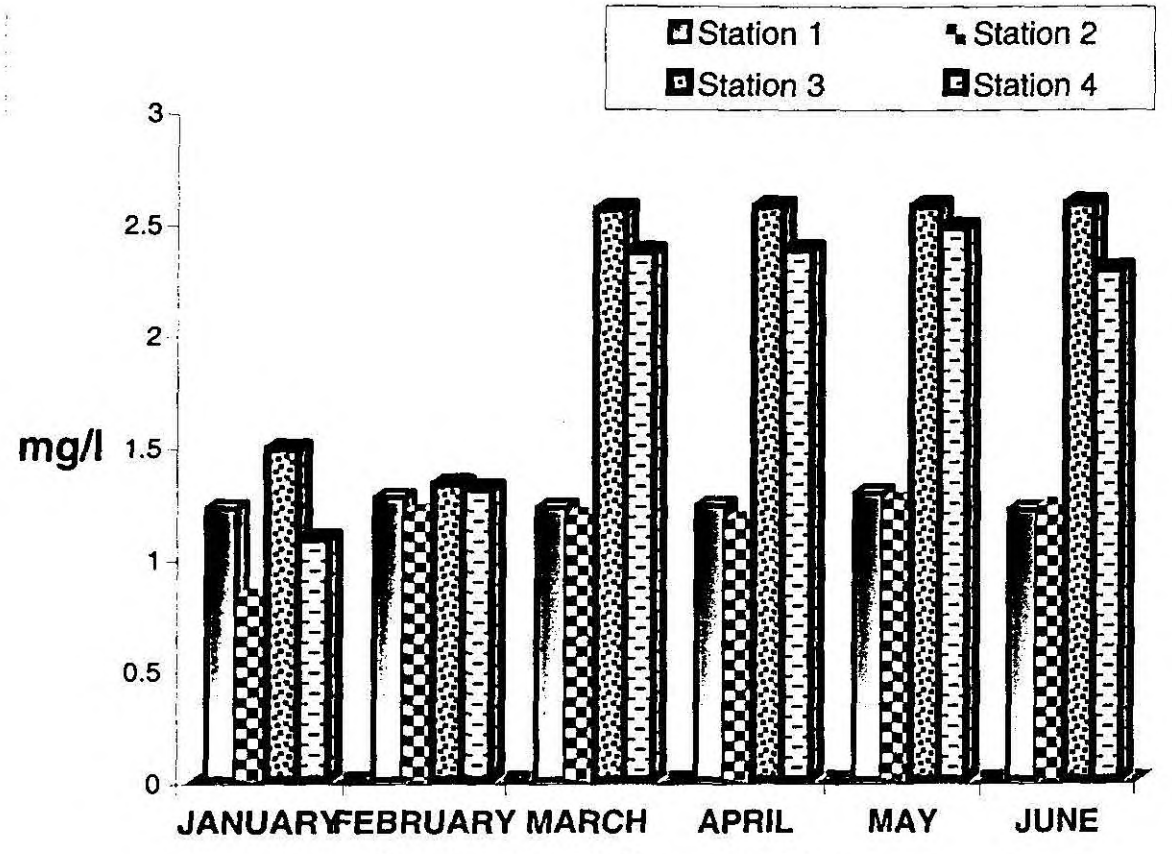


Figure-10.Chlorophyll a

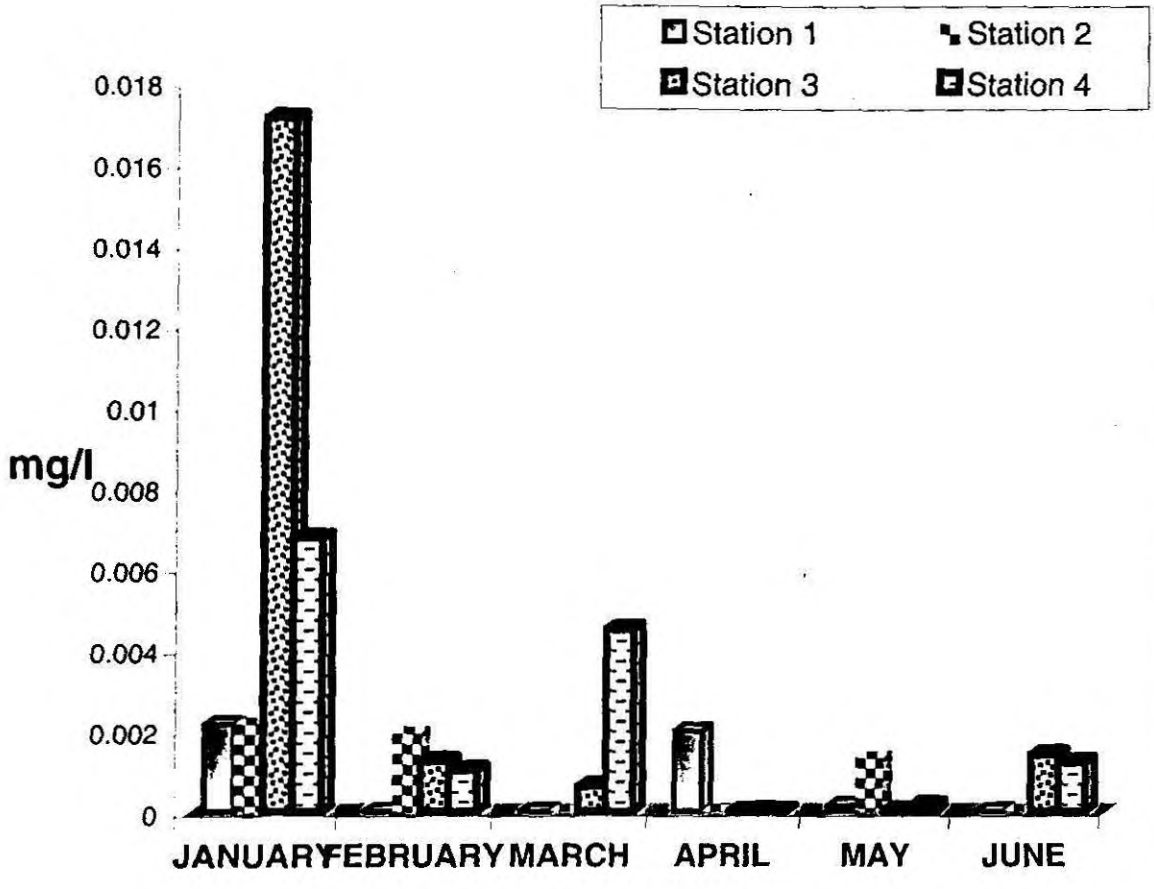


Figure-11.Chlorophyll b

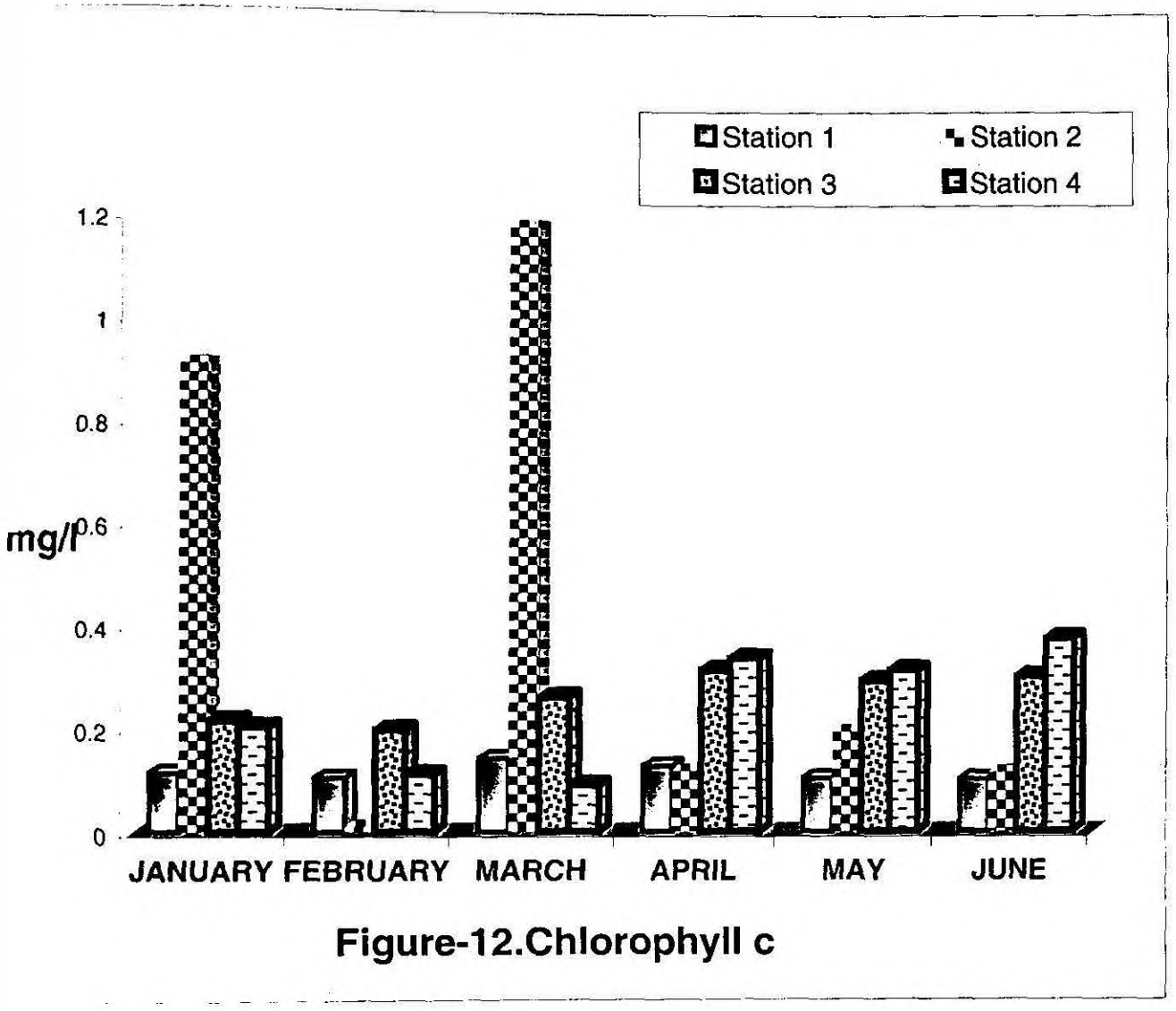


Figure-12.Chlorophyll c

value of 55.93-μg atom/l recorded in this station. The silicate readings in Station-3 fluctuated from 19.12 to 68.3-μg atom/l, while the highest and lowest values obtained during April and January respectively (Table-3). The mean silicate concentration was 48.56-μg atom/l in Station-3 during the study period. Among four stations the highest value of 74.872-μg atom/l was observed in Station-4 during April and the average concentration was 39.71-μg atom/l, where a minimum value of 19.27-μg atom/l was recorded in January.

4.1.10.Chlorophyll-a

Chlorophyll-a profiles are portrayed in the Figure-10; the values vary significantly among the stations ($P<0.05$), (Table-35.) In Station-1, gradual variations ranged from 1.212-mg/m^3 to 1.2971 mg/m^3 in June and May respectively (Table-1). In Station-2, the values were fluctuating between 0.8233 and 1.27mg/m^3 while a maximum concentration was exhibited during May; the minimum was in May (Table-2). The Chlorophyll-a values of Station-3 were in the range of 2.501 and 1.31 mg/m^3 in May and February respectively (Table-3). The highest value of 2.61 mg/m^3 obtained in Station-4 during June; where as the least value of 1.33 mg/m^3 was recorded in February. (Table-4).

4.1.11.Chlorophyll-b

There was no significant different exhibited in chlorophyll-b values among the stations ($P>0.05$), are represented in Table-35. The chlorophyll-b regime of the various stations showed in the Figure-11. In Station-1 the chlorophyll-b values varied in between 0.0 and 0.00214 mg/m^3 (Table-1). Highest value was observed in January and April, while chlorophyll-b was absent in other months during the period of investigation. The chlorophyll-b values of Station-2 fluctuated in between 0 and 0.002 mg/m^3 (Table-2), The chlorophyll-b exhibited almost the same pattern in Station-3 and 4 as that of Station-2 with the values ranging from 0.0 to 0.01 mg/m^3 (Table -3 &4).

4.1.12.Chlorophyll-c

Chlorophyll-c exhibit significant difference among the stations and the values presented as histogram in the figure-12. In Station-1, the chlorophyll-c ranged

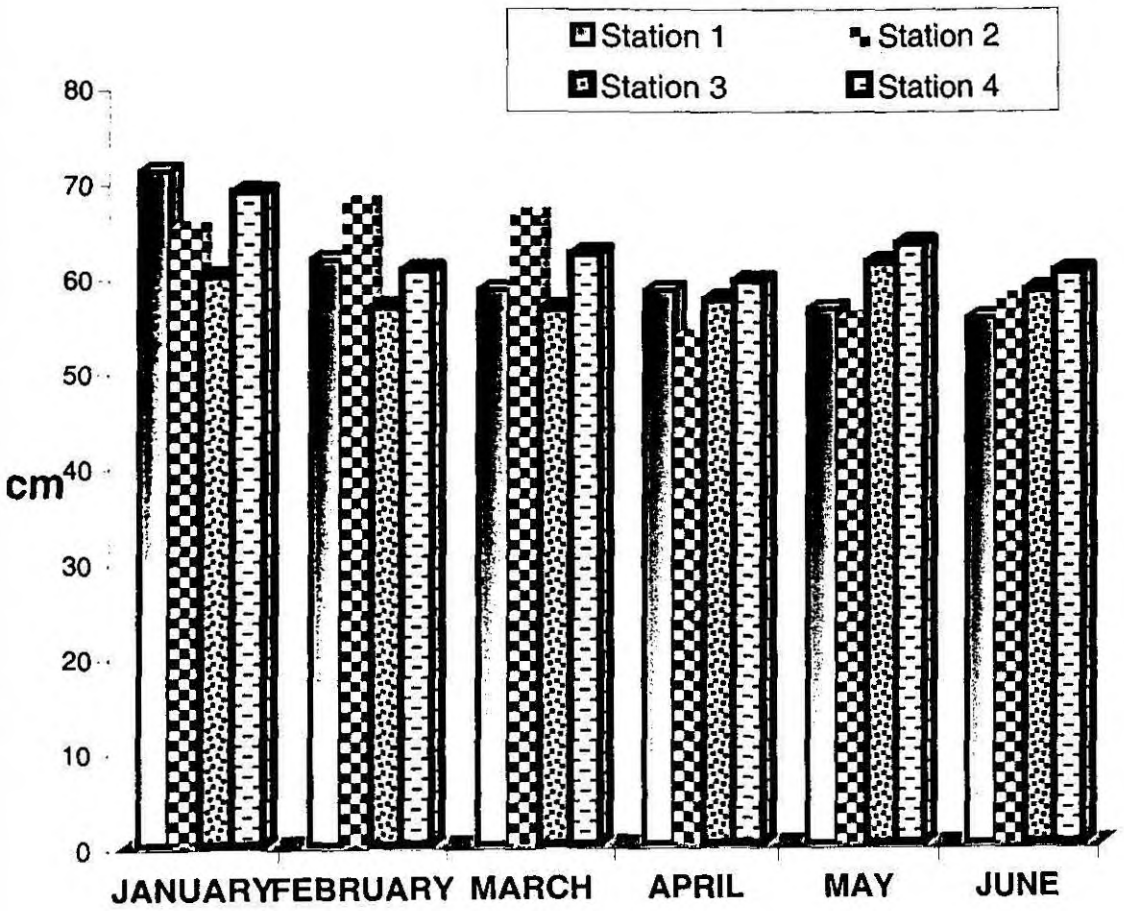


Figure-13.Transparency

Water Parameters	P' Value
Temperature	0.021
PH	0.454
Salinity	0
Dissolved Oxygen	0.047
Ammonia	0
Nitrite-N	0.097
Nitrate-N	0.446
Phosphate	0
Silicate	0.372
Chlorophyll a	0.0353
Chlorophyll b	0.569
Chlorophyll c	0.041
Transparency	0

Table-35.Correlations of Physicochemical Characteristics of water

Parameters	January	February	March	April	May	June
pH	7.73	7.9	7.8	7.01	7.12	7.46
Organic carbon (%)	2.2	1.337	1.874	1.735	1.62	1.91
Ammonia (ppm)	0.2672	0.289	0.2074	0.488	0.213	0.38
Nitrite (ppm)	0.3275	0	0	0.311	0	0.14
Nitrate (ppm)	4.5	2.3	0.983	0.412	0.631	0.84
Phosphorus (ppm)	52.91	50	120.12	47.47	58.31	59.71
Potassium (ppm)	68	66	69	125	83	73

Table-5.Station 1 Sediment characteristics.

Parameters	January	February	March	April	May	June
pH	7.35	7.38	7.3	6.96	7.11	7.01
Organic carbon (%)	6.13	6.2	4.99	12.35	10.13	7.8
Ammonia (ppm)	0.178	0.143	0.125	0	0.182	0.101
Nitrite-N (ppm)	0	0	0	0.1225	0	0.113
Nitrate-N (ppm)	1.004	0.9853	0.8912	0.223	0.412	0.921
Phosphorus (ppm)	77.8	70	77.2	47.18	63.1	66.39
Potassium (ppm)	275	263	450	175	221	198

Table-6. Station 2 sediment characteristics

Parameters	January	February	March	April	May	June
pH	7.63	7.71	7.7	6.93	7.01	7.1
Organic carbon (%)	7.592	7.425	7.921	8.708	7.941	8.1
Ammonia (ppm)	0.1443	0.1206	0.1687	0.193	0.1012	0.171
Nitrite-N (ppm)	0.495	0	0	0	0.1935	0.163
Nitrate-N (ppm)	0.6143	0	0	0.5629	0.7913	0.565
Phosphorus (ppm)	312.7	106	104	193.62	187.13	132.6
Potassium (ppm)	275	288	380	275	291	260

Table-7 Station 3 sediment characteristics

Parameters	January	February	March	April	May	June
pH	7.1	7.3	7.4	7.01	7.1	7.2
Organic carbon (%)	11.265	8.5	6.857	6.326	6.92	6.57
Ammonia (ppm)	0.1824	0.2931	0.289	0.171	0.189	0.175
Nitrite-N (ppm)	0	0	0	0.161	0.112	0.0972
Nitrate-N (ppm)	0.131	0.018	0	0.182	0.271	0.173
Phosphorus (ppm)	42.67	46	35.75	93.23	85.6	68.6
Potassium (ppm)	350	310	450	180	240	330

Table-8.Station 4 sediment characteristics

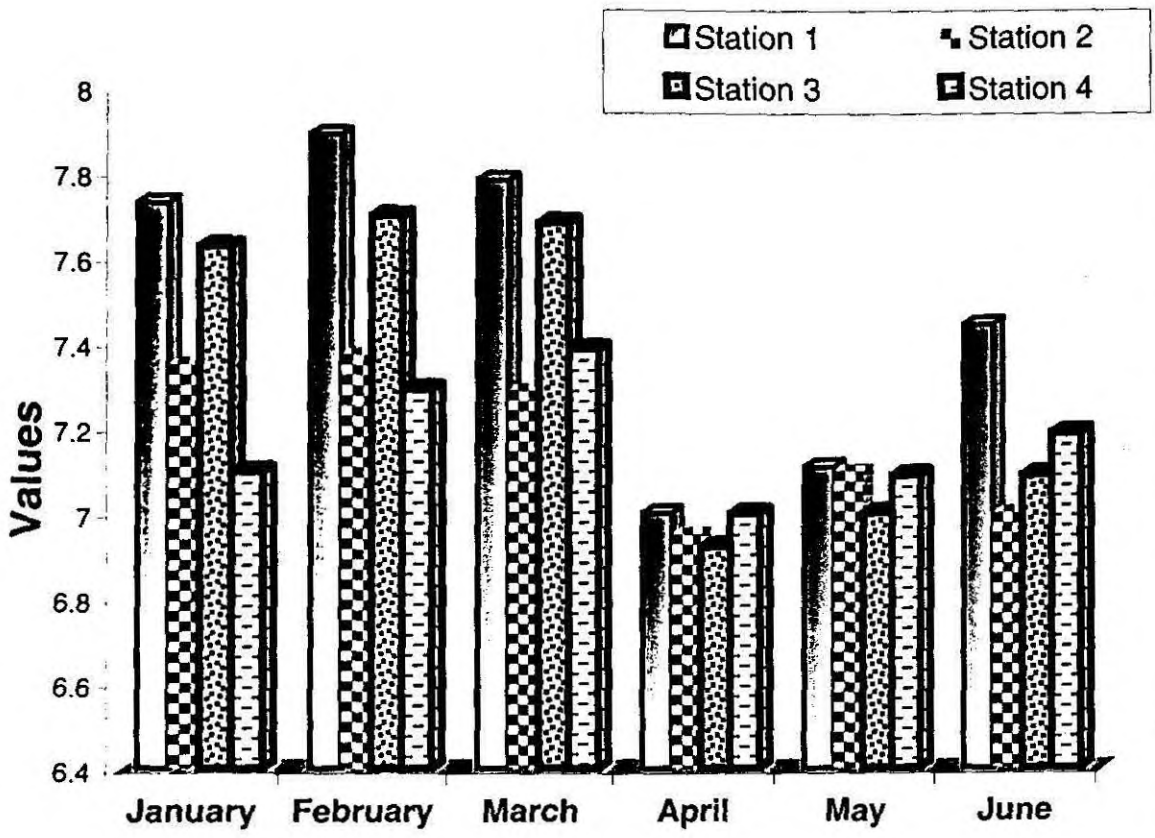


Figure-14. Sediment pH

from 0.1012 mg/m^3 to 0.142 mg/m^3 obtained in June and March respectively. It varied in Station-2 from 0.009 mg/m^3 in February to 1.182 mg/m^3 in March. The highest value of 0.376 mg/m^3 obtained in June and the lowest value of 0.089 mg/m^3 recorded in March in Station-3. In Station-4 Chlorophyll-c values were fluctuated in between 0.314 mg/m^3 and 0.197 mg/m^3 during February and April respectively.

4.1.13.Transparency

The transparency values of four stations are plotted in the Figure-13 and the Secchi disc extinction depth exhibited significant difference among the stations ($P<0.05$). The readings of Station-1 varied in between 56 and 71cm with mean value of 62.8cm (Table-1), and the highest value recorded in January and the lowest recorded in June. The fluctuation was in between 54 and 68cm in Station-2, where as the maximum value was observed in February and the minimum recorded in April (Table-2). Fluctuations were less in Station-3 with the maximum of 62cm in May and the minimum value of 57cm in February and March (Table-3). Comparatively higher transparency values exhibited in Station-4, where the peak value of 69cm was obtained in January and least value of 60cm was observed in April (Table-4).

4.2. Sediment characteristics

4.2.1. pH

pH values of the sediment, associated with the mangrove stations didn't exhibit any significant difference ($P>0.05$) and the values are shown in Figure-14. In Station-1, the pH readings fluctuated between 7.01 in April and 7.9 in February while the mean pH was 7.5 (Table-5). pH value of Station-2 ranged from 6.96 to 7.38, the higher value observed during January, February and March, and the lowest pH was observed in April with the mean reading of 7.185 (Table-6). Considerable variations were noticed in Station-3 with a maximum value of 7.71 during February and the minimum value of 6.93 in April (Table-7). The pH values of Station-4 exhibited the same pattern of fluctuations while the values were ranged from 7.01 to 7.4 (Table-8).

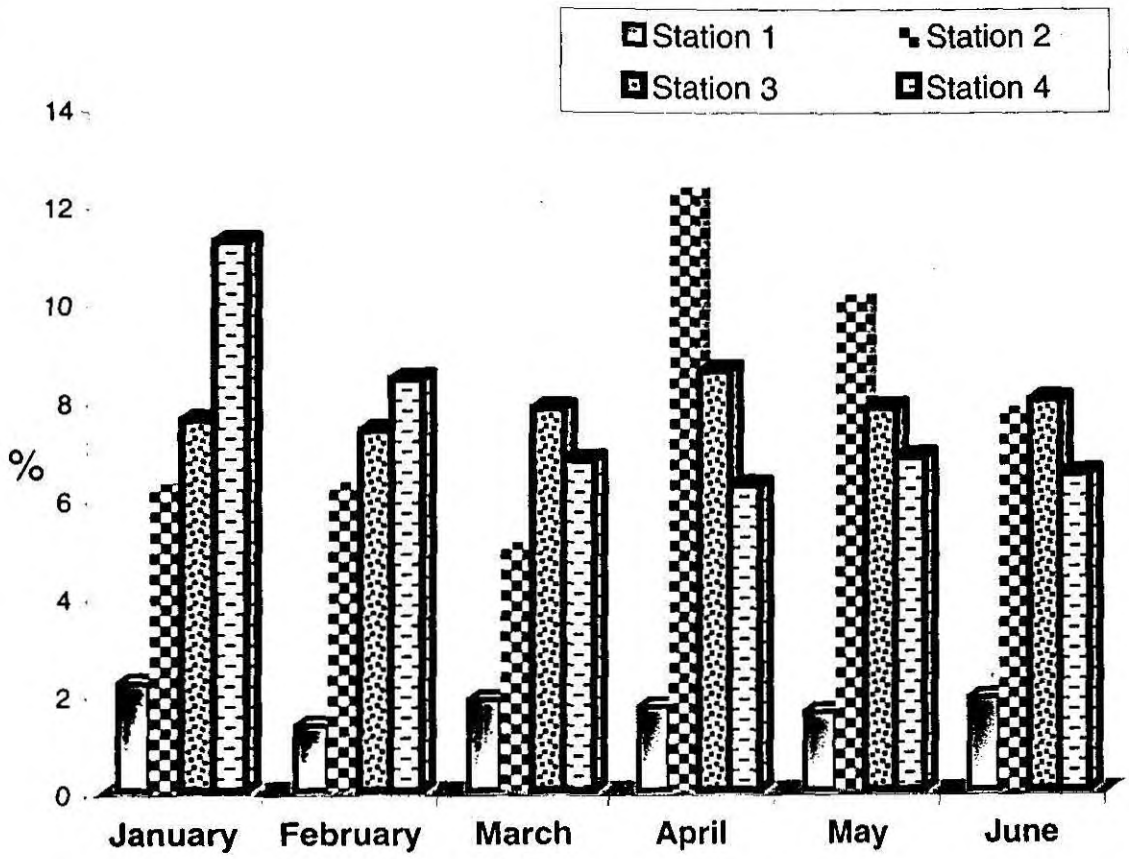


Figure- 15.Organic carbon

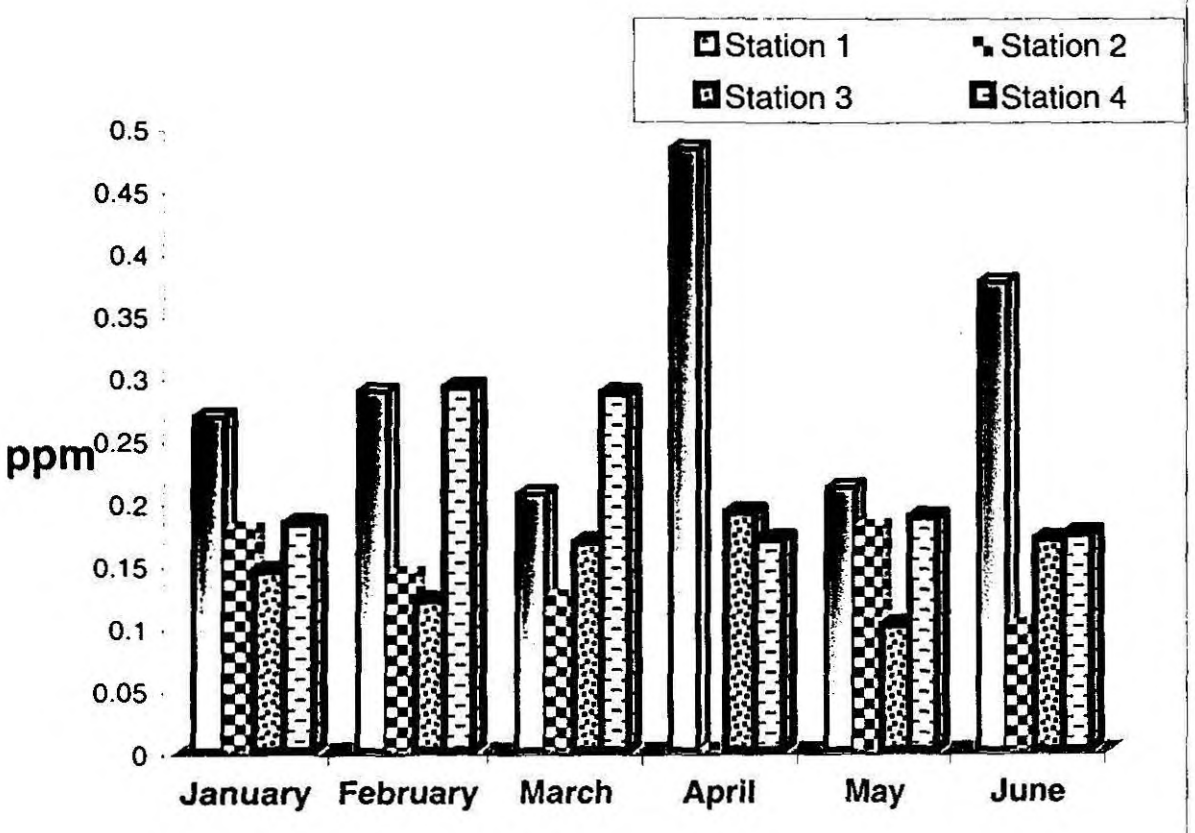


Figure-16.Ammonia

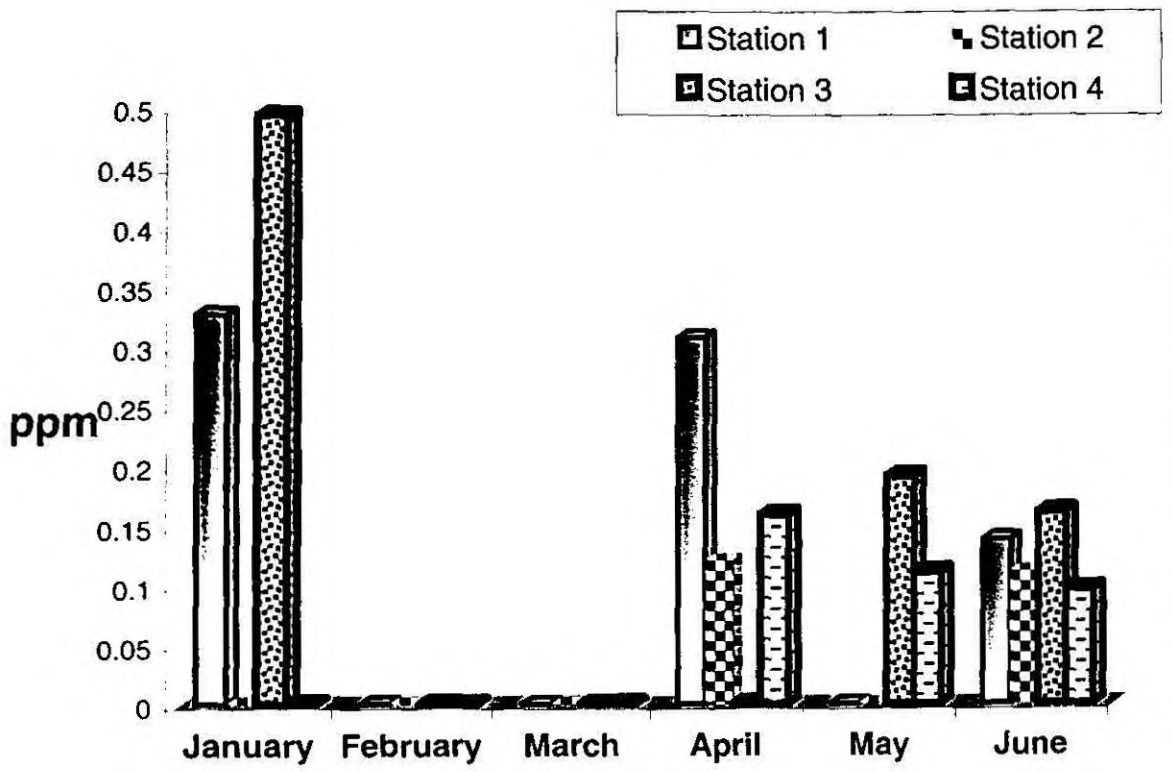


Figure-17.Nitrite

4.2.2. Organic carbon

Organic carbon differed significantly among the stations ($P<0.05$) and the regime is shown in the Figure-15. In Station-1 the organic carbon varied from 1.337% to 2.2% (Table-5), where highest and lowest were recorded in January and February respectively with the average reading of 1.78%. The organic carbon content of Station-2 fluctuated in between the maximum value of 12.35% in April and the minimum value of 4.99% in March with the mean value of 7.9% during the study period (Table-6). Organic carbon values of Station-3 varied between 7.425% and 8.708% in February and April respectively (Table-7). Comparatively the highest value of 11.265% was obtained in Station-4 during January, while the lowest value of 6.326% recorded in April with a mean value of 7.74% during period of investigation (Table-8).

4.2.3. Ammonia

Ammonia values showed significant difference among the stations ($P<0.05$) and the values are graphically represented in the Figure-16. The ammonia concentrations in Station-1 varied between 0.2074ppm and 0.488ppm, while the highest and lowest values were observed in April and March respectively with the average reading of 0.307ppm (Table-5). In Station-2, the ammonia concentrations fluctuated in between a maximum concentration of 0.182ppm in May and a minimum of 0.0 in April (Table-6). The average concentration was 0.122ppm in this Station-2. The highest and lowest NH_4 were observed in Station-3, where the crest and trough values were 0.193ppm and 0.1012ppm in April and May respectively (Table-7). The values in Station-4 varied from 0.171ppm to 0.2931ppm, where the peak reading was in February and least was in April (Table-8).

4.2.4. Nitrite-N

Nitrite values of four stations didn't differ significantly ($P>0.05$), and the values are shown in Figure-17. Research area is often experienced nil nitrite values during the study period. In Station-1, highest values were found in January and April, which was around 0.31ppm (Table-6). Nitrite value of Station-2 rose to the maximum of 0.1225ppm in April. Comparatively the highest nitrite value of 0.495ppm was accounted in Station-3 during January with the mean value of 0.142ppm. NO_2-N

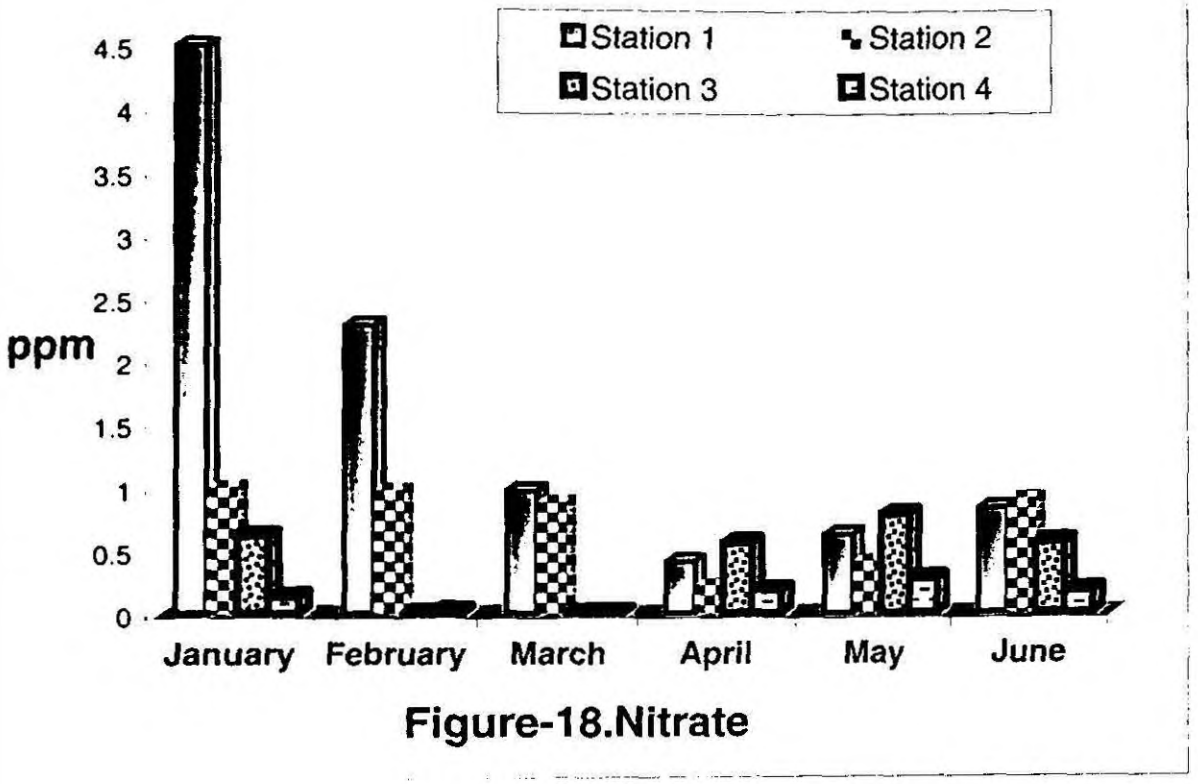


Figure-18.Nitrate

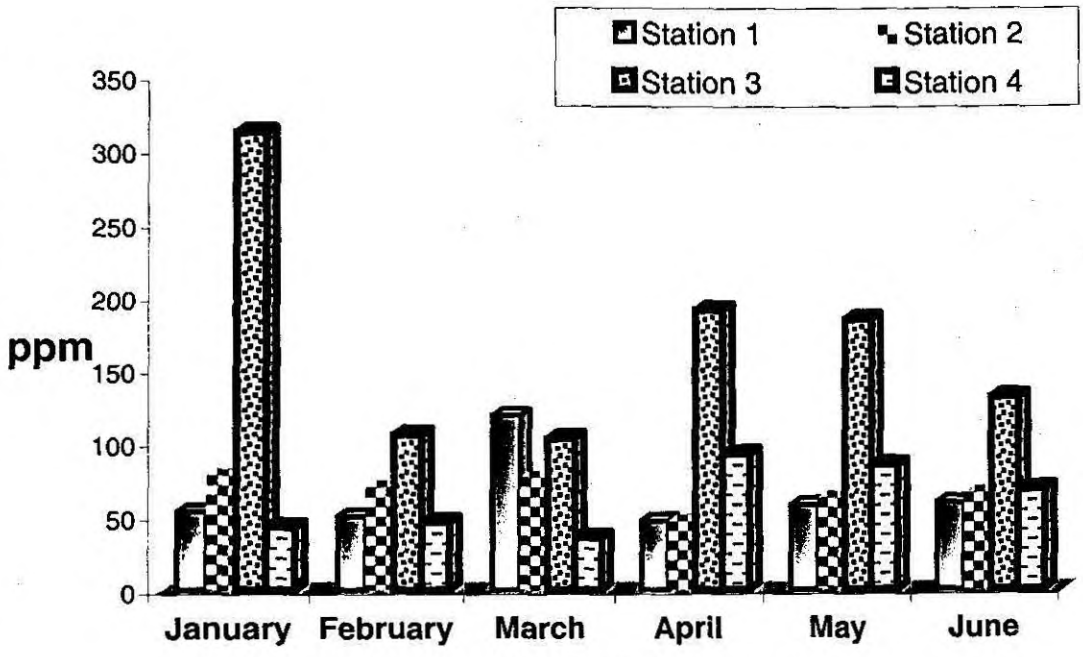


Figure-19.Available Phosphorus

readings of Station-4 fluctuated in between 0 and 0.161ppm. Maximum and minimum values were recorded in April and January to March respectively.

4.2.5. Nitrate-N

Nitrate concentrations of four Stations sediment are shown in Figure-18 and the values exhibited significant variations among the stations ($P<0.05$). In Station-1, the nitrate readings varied from 0.412 to 4.5ppm, while the peak value was observed in January and the least concentration in April with the mean value of 1.611ppm (Table-5). Higher values were often associated with the Station-2; while highest value of 1.004ppm was accounted at the onset of the study period where as lowest value of 0.223ppm was recorded in April (Table-6) with mean concentration of 0.74ppm. The nitrate concentration of Station-3 fluctuated in between the maximum of 0.7913ppm in May and the minimum of 0.0ppm in January and March where as the mean value was 0.4225ppm (Table-7). The nitrate concentrations of Station-4 were ranging from 0.0ppm to 0.21ppm and the maximum was obtained in May. NO_3-N was absent in March and the average concentration was 0.13ppm (Table-8).

4.2.6. Available phosphorus

The values didn't portray significant difference among the stations ($P>0.05$) and represented as a bar diagram in Figure-19. The phosphorus readings of Station-1 ranged from 47.47ppm to 120.12ppm, while the peak value was observed in March and least was noticed in April (Table-5). The average phosphorus concentration of Station-1 was 64.7ppm. The phosphorus concentrations were fluctuating between a maximum of 77.8ppm and the minimum of 47.18ppm, which observed in January and April respectively in Station-2 (Table-6). Among four stations highest values accounted in Station-3, where the peak value observed was 312.7ppm with an average of 172ppm during the study period. The phosphorus values varied in between 104ppm in March and 312.7ppm in January (Table-7). In Station-4, the least value of 35.75ppm was noted in March and the mean concentration was 61.9ppm (Table-8); maximum value of 93.23ppm was recorded in April during the study period.

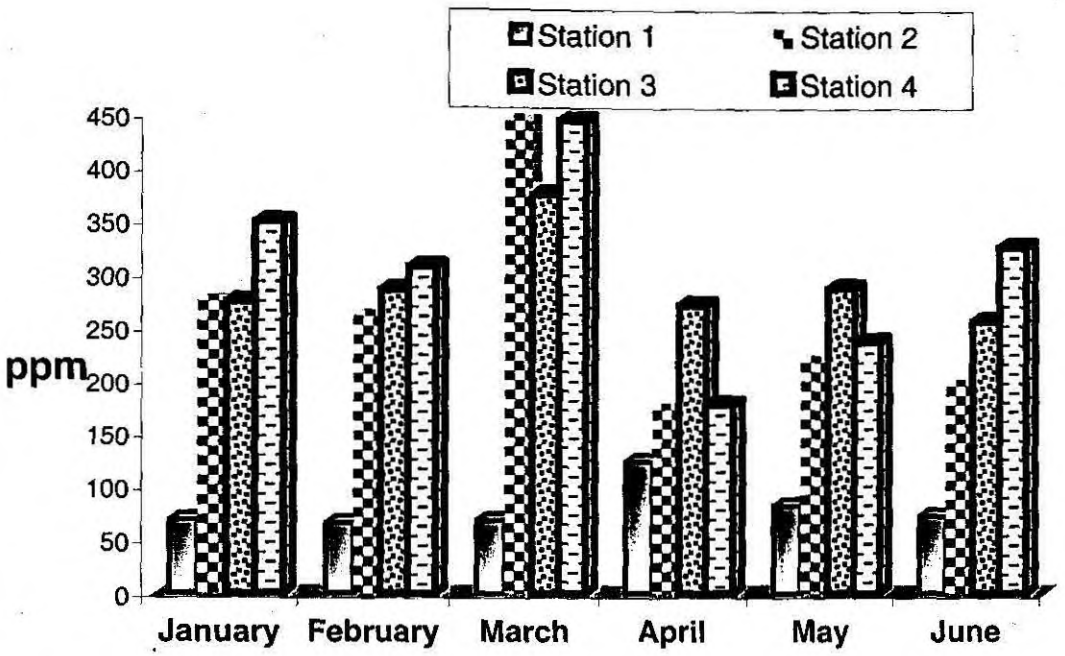


Figure-20.Potassium

Parameters	P' Value
PH	0.23
Organic carbon	0
Ammonia	0.001
Nitrite-N	0.825
Nitrate-N	0.029
Available phosphorus	0.094
Potassium	0

Table-36. Correlation of sediment parameters in four Stations

4.2.7. Potassium

Potassium values of four stations connected with the mangrove zone are pictured as a histogram in the figure-20 and the values are shown considerable variations between the stations ($P<0.05$). The potassium values of Station-1 were fluctuating between the minimum of 66ppm in February and a maximum of 125ppm in April with an average of 80.6ppm. (Table-5). Considerable fluctuations were observed in Station-2, where the values were ranged from 175ppm to 450ppm in April and March respectively (Table-6). The mean concentration of Potassium in Station-2 was 264ppm. In Station-3 the potassium values varied in between the minimum of 260ppm in June and maximum of 380ppm in March, where the average concentration was 295ppm. (Table-7). The potassium readings of Station-4 confined between 180ppm and 450ppm, where the peak value was noticed during March and least value was observed in April with an average of 310ppm in the entire study period (Table-8).

4.3. Phytoplankton

Phytoplankton identification and quantitative diversity analysis were done in the four stations, connected with the mangrove ecosystem and statistical analysis was done to ensure better data interpretation. The individuals per litre for the very common phytoplankton groups are listed in Table 10-13. Statistical tools such as indices of richness, evenness and diversity are given in Table: 23-26. Generally diatoms constituted the major composition in the total microalgae.

In Station-1, the phytoplankton ranged from 113360 to 155742-nos/l during the study period, while the peak value was observed in May and least in February (Table-10). Among various species listed in the table-10, Diatoms such as *Coscinodiscus, Pleurosigma, Navicula, Nitzschia* and *Thallasiosira* were dominated in Station-1, the number of *Coscinodiscus* varied in between 17,820 and 23,400 nos/l during February and January respectively. *Pleurosigma* counts were fluctuating between 16,920 nos/l in January and 24,100 nos/l in February, which is the highest count of individual species profile in Station-1 during the study period. The maximum density of *Navicula* noted was 18,120 nos/l in April and the minimum 14,212 nos/l observed in May. The *Nitzschia* was high in February and very low

Phytoplankton:

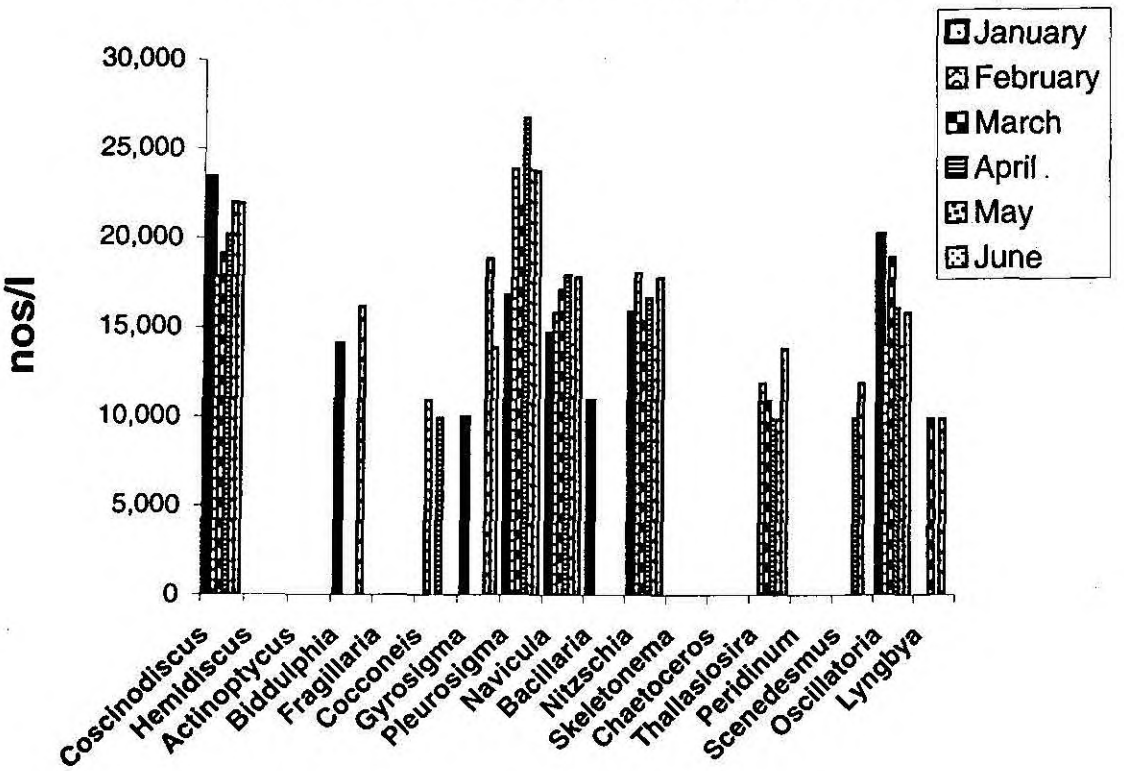
Months	Open water		Canal mouth		Mangrove 1		Mangrove 2	
	Plankton Volume	Plankton count /l	Plankton Volume	Plankton Count/l	Plankton Volume	Plankton Count/l	Plankton Volume	Plankton Count/l
January	0.8ml	1,26,630	0.8ml	1,02,820	1ml	1,48,360	1ml	99,560
February	1ml	1,13,360	0.5ml	77,660	1.5ml	1,39,320	1.3ml	84,590
March	1ml	1,14,090	0.5ml	1,04,060	2ml	1,57,630	2ml	1,32,270
April	1.5ml	1,28,380	0.8ml	1,23,510	1.6ml	1,70,060	2.5ml	1,16,580
May	2ml	1,55,742	1ml	1,53,145	2.5ml	1,89,940	2.6ml	1,41,120
June	1.3ml	1,25,930	0.9ml	1,43,000	2ml	1,22,000	2.2ml	86,340

Table-9.Total plankton Cell Estimation

Species	January	February	March	April	May	June
Coscinodiscus	23,400	17,820	19,140	20,180	22,010	21,930
Hemidiscus	0	0	0	0	0	0
Actinoptycus	0	0	0	0	0	0
Biddulphia	14,100	0	0	0	16,210	0
Fragillaria	0	0	0	0	0	0
Cocconeis	0	11,000	0	10,000	0	0
Gyrosigma	10,000	0	0	0	19,000	14,000
Pleurosigma	16,920	24,100	22,000	27,000	24,080	24,000
Navicula	14,810	16,000	17,280	18,120	14,212	18,000
Bacillaria	11,000	0	0	0	0	0
Nitzschia	16,000	18,240	15,540	16,820	14,100	18,000
Skeletonema	0	0	0	0	0	0
Chaetoceros	0	0	0	0	0	0
Thallasiosira	0	12,000	11,000	10,000	10,000	14,000
Peridinum	0	0	0	0	0	0
Scenedesmus	0	0	0	10,000	12,000	0
Oscillatoria	20,400	14,200	19,130	16,260	14,130	16,000
Lyngbya	0	0	10,000	0	10,000	0
Total	1,26,630	1,13,360	1,14,090	1,28,380	1,55,742	125,930

Table-10. Station 1 Phytoplankton Cells/l

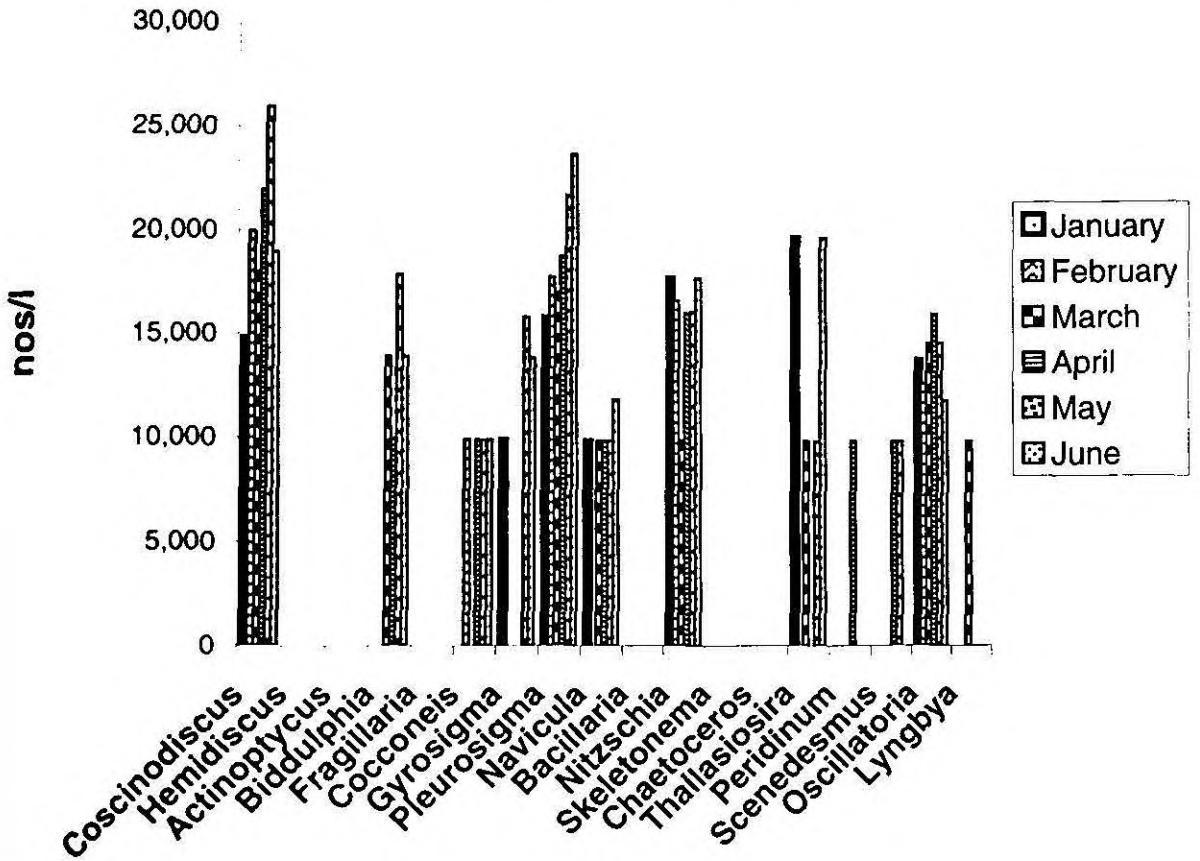
Figure-21.Station 1 Phytoplankton



Species	January	February	March	April	May	June
Coscinodiscus	14,820	20,000	18,000	22,000	26,000	19,000
Hemidiscus	0	0	0	0	0	0
Actinophycus	0	0	0	0	0	0
Biddulphia	0	0	14,000	10,000	18,000	14,000
Fragillaria	0	0	0	0	0	0
Cocconeis	0	10,000	0	10,000	10,000	10,000
Gyrosigma	10,000	0	0	0	16,000	14,000
Pleurosigma	16,000	18,000	17,250	19,000	22,000	24,000
Navicula	10,000	0	10,000	10,000	10,000	12,000
Bacillaria	0	0	0	0	0	0
Nitzschia	18,000	16,850	10,000	16,260	16,325	18,000
Skeletonema	0	0	0	0	0	0
Chaetoceros	0	0	0	0	0	0
Thallasiosira	20,000	0	10,000	0	10,000	20,000
Peridinum	0	0	0	10,000	0	0
Scenedesmus	0	0	0	10,000	10,000	0
Oscillatoria	14,000	12,810	14,810	16,250	14,820	12,000
Lyngbya	0	0	10,000	0	0	0
Total	1,02,820	77,660	1,04,060	1,23,510	1,53,145	1,43,000

Table-11. Station 2 Phytoplankton cells/l

Figure-22.Station 2 Phytoplankton



during May in Statiion1, where the peak and least counts were 18,240 and 14,100 nos/l respectively. *Thallasiosira* constituted highest concentration during June, which recorded 14,000 nos/l and the average was of 9500 nos/l in Station-1.The density of blue green algae-*Oscillatoria* of Station-1 varied in between 14,130 nos/l in May and 20,400 nos/l in January. While the other species such as *Biddulphia, Cocconeis,* Green algae *Scenedesmus* and *Lyngbya* of Cyanophyceae showed only sporadic occurrence in smaller concentration the Study period.

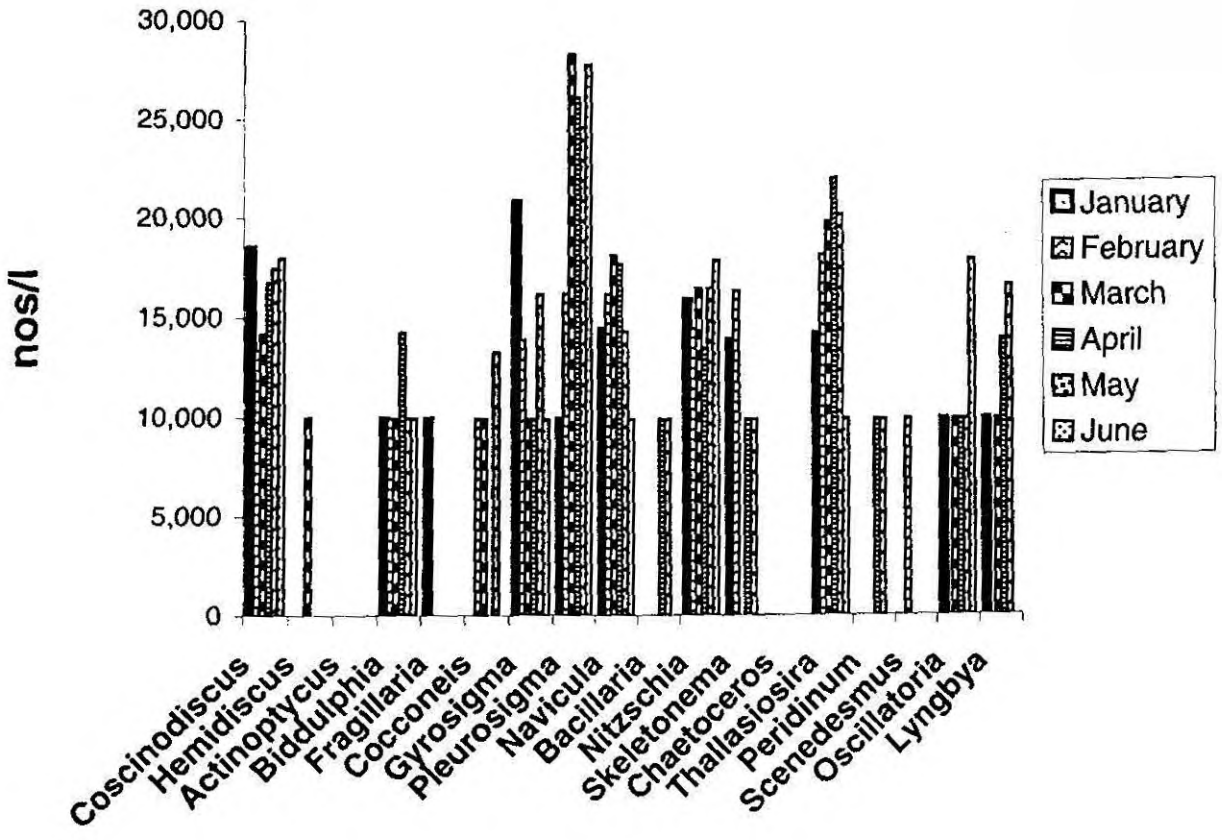
The microalgae of Station-2 fluctuated in between the minimum of 77,660 nos/l in February and maximum of 1,43,000 nos/l in June, where *Pleurosigma* dominated the composition in the total cell counts (Table-11). The density *Coscinodiscus* were ranging from 14,820 to 26,000 nos/l in January and May respectively. *Biddulphia* showed the peak during the last period of study period, while the highest concentration was 18,000nos/l in May and the lowest reported was 10,000nos/l in April. *Cocconeis* showed a constant presence of 10,000nos/l during February, April, May and June. *Gyrosigma* count of Station-2 recorded a moderate populace of 16,000 nos/l in May and 14,000 nos/l in June. *Pleurosigma* showed maximum value of 24,000 nos/l during June and the minimum of 16,000 nos/litre in January. *Navicula* exhibited a constant density of 10,000 nos/l in all the months except in February, where the species was totally absent. Remarkable fluctuations could be seen in the *Nitzschia* profile of Station-2, where the counts were fluctuating between the minimum of 10000 nos/l in March and the maximum of 18,000 nos/l during January and June. The maximum of 20,000 nos/l of *Thallasiosira* was during January and June where as a minimum of 10,000 nos/l was recorded in March and May. *Oscillatoria* represented the Cyanophyceae group in Station-2 where the peak was found to be 14,810 nos/l in March with least count of 12,000 nos/l in June. *lyngbya* and dinoflagellate-*peridinum* were exhibited their presence in rare numbers during March and April in Station-2.

Comparatively higher density of phytoplankton was oftenly observed in Station-3, where the peak concentration of 1,89,940 nos/l was recorded in May, and the least value was 1,22,000 nos/l (Table-12). Population of *Coscinodiscus* ranged from 13,360 nos/l to 18,520 nos/l in February and January respectively. *Biddulphia* showed a constant presence of 10,000cells/litre in all the months except in April,

Species	January	February	March	April	May	June
Coscinodiscus	18,520	13,360	14,220	16,780	17,500	18,000
Hemidiscus	0	0	10,000	0	0	0
Actinophycus	0	0	0	0	0	0
Biddulphia	10,000	10,000	10,000	14,320	10,000	10,000
Fragillaria	10,000	0	0	0	0	0
Cocconeis	0	10,000	10,000	0	13,310	0
Gyrosigma	21,000	14,000	10,000	10,000	16,300	10,000
Pleurosigma	10,000	16,320	28,510	26,350	24,810	28,000
Navicula	14,530	16,310	18,300	17,810	14,400	10,000
Bacillaria	0	0	0	10,000	10,000	0
Nitzschia	16,000	14,550	16,600	13,580	16,600	18,000
Skeletonema	14,000	16,480	0	10,000	10,000	0
Chaetoceros	0	0	0	0	0	0
Thallasiosira	14,310	18,300	20,000	22,220	20,310	10,000
Peridinum	0	0	0	10,000	10,000	0
Scenedesmus	0	10,000	0	0	0	0
Oscillatoria	10,000	0	10,000	10,000	10,000	18,000
Lyngbya	10,000	0	10,000	14,000	16,710	0
Total	1,48,360	1,39,320	1,57.630	1,75,060	1,89.940	1,22,000

Table-12. Station 3 Phytoplankton cells/l.

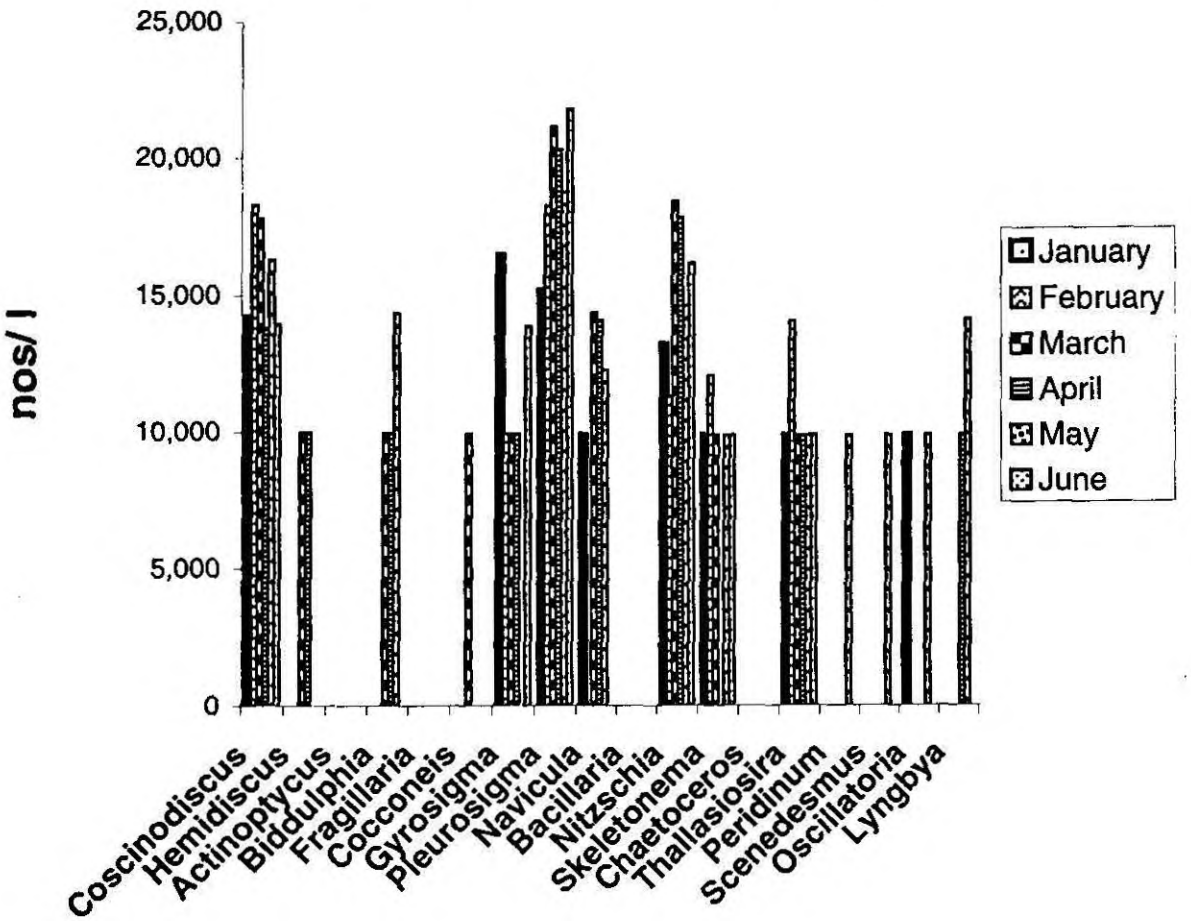
Figure-23.Station 3 Phytoplankton



Species	January	February	March	April	May	June
Coscinodiscus	14,240	18,300	17,810	13,820	16,320	14,000
Hemidiscus	0	0	10,000	10,000	0	0
Actinophycus	0	0	0	0	0	0
Biddulphia	0	0	10,000	10,000	14,410	0
Fragillaria	0	0	0	0	0	0
Cocconeis	0	0	10,000	0	0	0
Gyrosigma	16,600	10,000	10,000	10,000	0	14,000
Pleurosigma	15,340	18,410	21,340	20,500	18,920	22,000
Navicula	10,000	0	14,510	14,240	12,410	0
Bacillaria	0	0	0	0	0	0
Nitzschia	13,380	11,420	18,610	18020	14,780	16,340
Skeletonema	10,000	12,220	10,000	0	10,000	10,000
Chaetoceros	0	0	0	0	0	0
Thallasiosira	10,000	14240	10,000	10,000	10,000	10,000
Peridinum	0	0	0	0	10,000	0
Scenedesmus	0	0	0	0	10,000	0
Oscillatoria	10,000	0	0	0	10,000	0
Lyngbya	0	0	0	10,000	14,280	0
Total	99,560	84,590	1,32,270	1,16,580	1,41,120	86,340

Table-13. Station 4 Phytoplankton cells/l.

Figure-24.Station 4 Phytoplankton



where the count was14,320 nos/l. Maximum *Gyrosigma* obtained in January and the minimum was in March with the numbers of 21,000 and 10,000 nos/l respectively. *Pleurosigma* had the highest density of 28,510 nos/l in March and the lowest of 10,000 nos/l in January. Considerable fluctuations were observed in the *Navicula* density with a maximum value of 18,300 nos/l in March and a minimum of 10,000 nos/l in June. *Nitzschia* in Station-3 varied in between 13,580 nos/l in April and 18,000 nos/l in June. *Skeletonema* exhibited the maximum density of 16,480 nos/l during February in Station-3. Remarkable accounts could be noticed in *Thallasiosira* populace ranging from 10,000 to 22,220cells/litre could be observed in Station-3. Highest and lowest density observed during June and April respectively. The density of *Cocconeis* was found to be 13,310nos/l in May. Sporadic occurrence of *Hemidiscus, Fragillaria,* and *Scenedesmus* at a constant density of 10,000 nos/l. In Station-3 *Oscillatoria* had also been observed in the mangrove environment had a peak count of 18,000 nos/l in June in which the average density was found to be 10,000 nos/l in all other months. *Lyngbya* population ranged from 10,000 to 16,710 individuals/l and highest concentration was recorded in the month of May.

Phytoplankton community of Station-4 ranged between 84,590 nos/l and 1,41,120 nos/l while the highest and lowest density were detected during May and February respectively. *Coscinodiscus* showed considerable variations during the period of study. The counts were ranging from 13,820 to 18,300 nos/litre. *Biddulphia* exhibited its presence thrice in the six months period, where the maximum density was 14,410 nos/l recorded in May. *Gyrosigma* exhibited the highest occurence of 16,600 nos/l in January. *Pleurosigma* density varied in between 15,340 nos/l and 22,000 nos/l in January and June. *Navicula* showed the highest density of 14,510 nos/l in March. *Nitzschia* population fluctuated from the minimum value of 11,420 nos/l in February to the maximum of 18,610 nos/l in March. *Skeletonema* counts put a peak concentration of 12,220 nos/l in February. Rare occurrence of *Cocconeis, Peridinum, Thallasiosira, Scenedesmus* and *Oscillatoria* showed a maximum density of 10,000 nos/l while *Lyngbya* exhibited the higher density of 14,280 nos/l in May.

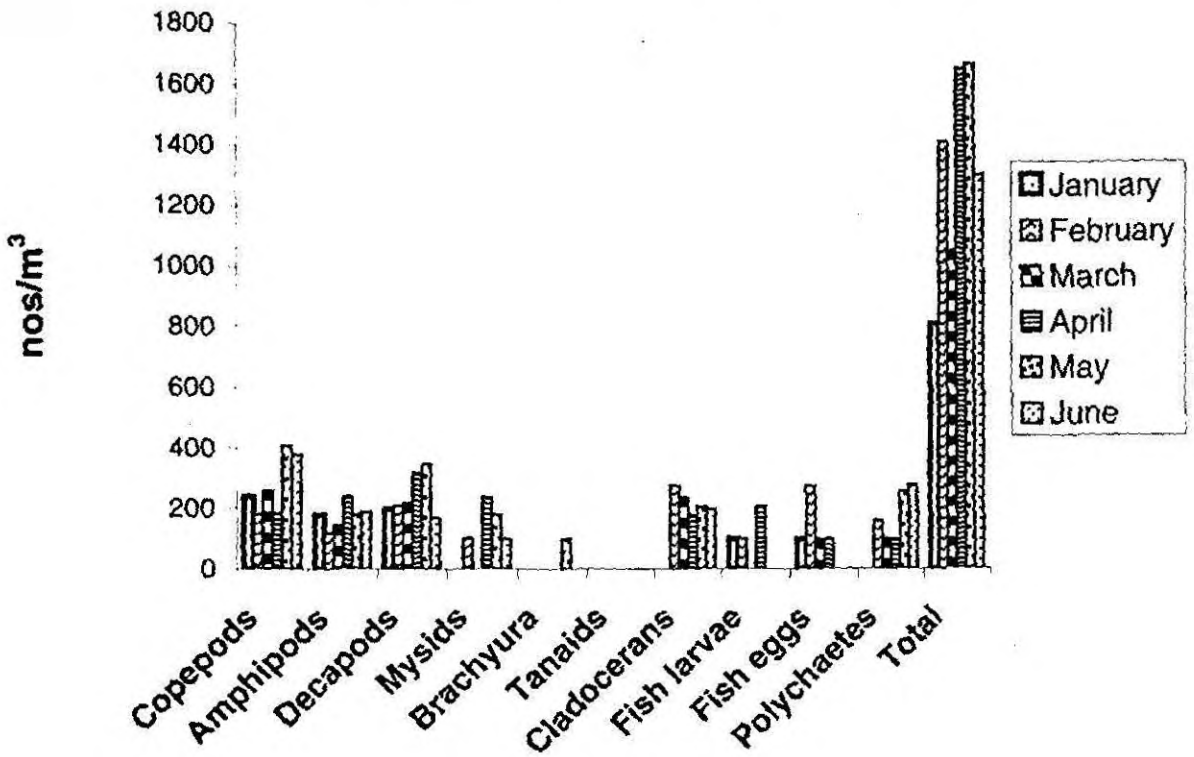
4.4. Zooplankton

Based on the occurrence and abundance of zooplankton two groups were recognized. The major groups encountered are Copepods, Amphipods,

Species	January	February	March	April	May	June
Copepods	240	180	260	185	410	380
Amphipods	180	120	145	240	180	190
Decapods	200	210	220	320	350	170
Mysids	0	100	0	240	180	100
Brachyura	0	0	0	0	100	0
Tanaids	0	0	0	0	0	0
Cladocera	0	280	240	180	210	200
Fish larvae	100	100	0	210	0	0
Fish eggs	100	280	100	100	0	0
Polychaetes	0	160	100	100	260	280
Total	820	1430	1065	1675	1690	1320

Table-14.Station 1 Zooplankton nos/m^3

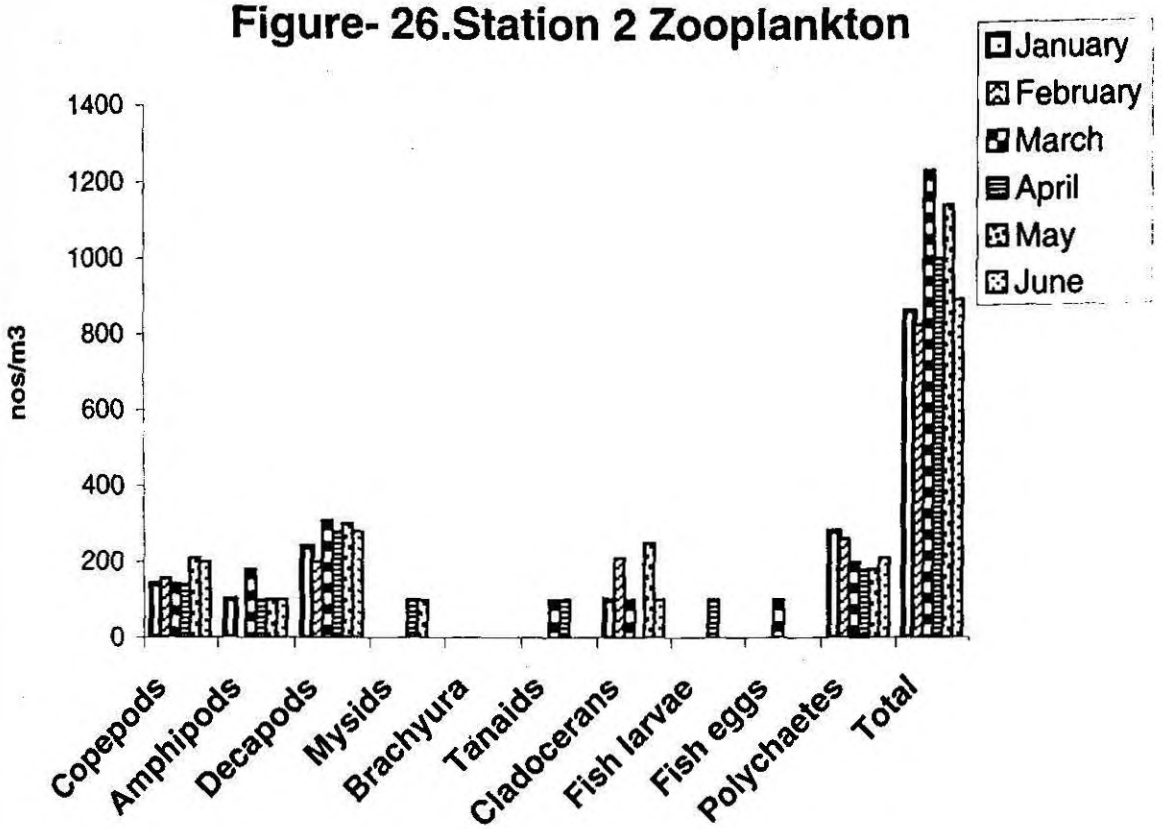
Figure-25.Station 1 Zooplankton



Species	January	February	March	April	May	June
Copepods	140	155	142	140	210	200
Amphipods	100	0	180	100	100	100
Decapods	240	200	310	280	300	280
Mysids	0	0	0	100	100	0
Brachyura	0	0	0	0	0	0
Tanaids	0	0	100	100	0	0
Cladocera	100	210	100	0	250	100
Fish larvae	0	0	0	100	0	0
Fish eggs	0	0	100	0	0	0
Polychaetes	280	260	200	180	180	210
Total	860	825	1232	1000	1140	890

Table-15. Station 2 Zooplankton nos/m^3

Figure- 26.Station 2 Zooplankton



Decapods, Cladocera, Polychaetes and Fish larvae, their Occurrence profile at various stations are shown in Table 14-17. Statistical indices for Zooplankton in the stations connected with the mangrove are presented in Table 27-30. Mysids, Brachyura larvae and Tanaids were regarded as minor group. Zooplanktons which were rare and in very small quantity such as Actinarians, Tanaids, Halobetes, Aplysia and flatfish larvae are represented in Table-18. The numbers of zooplankton/m^3 at four stations are exhibited in Figure 25-28.

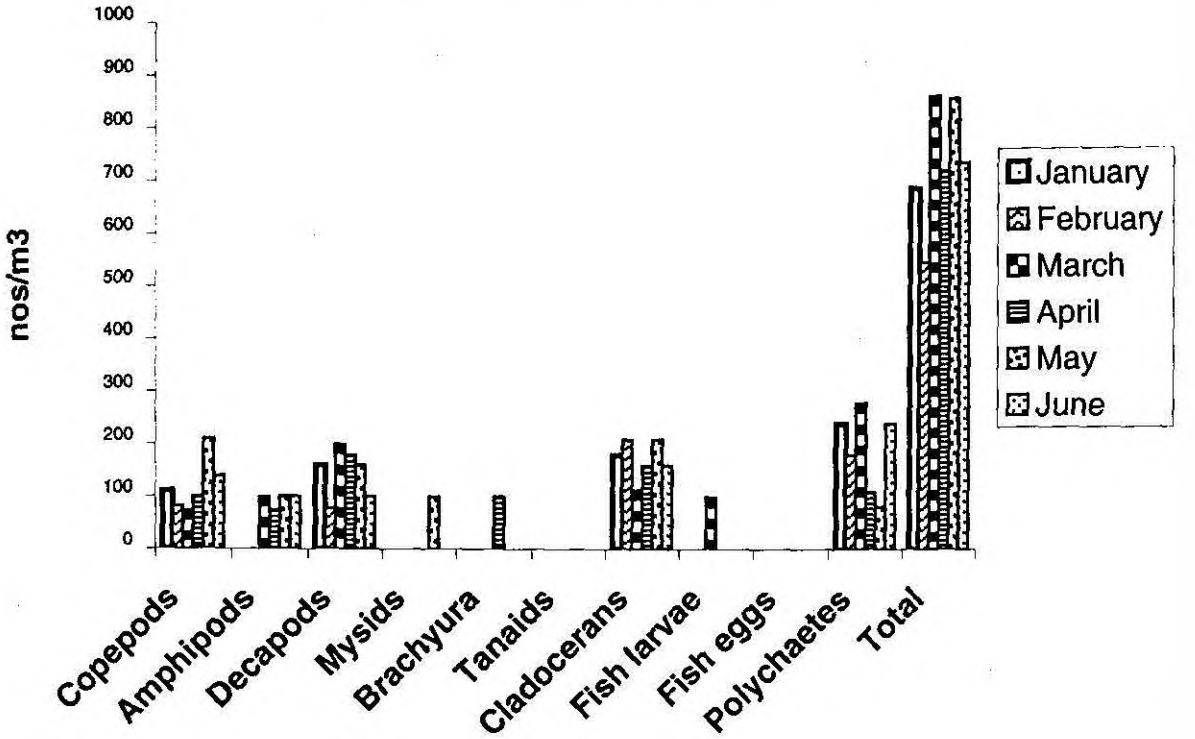
The total zooplankton of Station-1 reached the maximum number in May and its corresponding value was 1690nos/ m^3 and the lowest of 820nos/m^3, was detected during January (Table-14). Copepods exhibited maximum numbers during May and a minimum observed in February with the density ranging from 180 to 410nos/ m^3. Amphipods were shown a very high propagation of 240nos/ m^3 during April and the lowest 120nos/ m^3 in February. The maximum number of Decapod population was 350nos/ m^3 in May and minimum was 170nos/ m^3 in June. Mysids were very low in February and June while the highest concentration of 240nos/ m^3 was observed in April. Cladocera showed a peak in February and lowest density in April with the respective presence of 180 nos/ m^3 and 280nos/ m^3. Fish larvae was maximum in April with 210nos/ m^3 and the minimum was 100nos/m^3 obtained during January and February. The density of fish eggs was maximum with 280nos/ m^3 obtained in February. Polychaetes exhibited maximum distribution of 280nos/ m^3 in June and minimum of 100nos/ m^3 during March and April.

In Station-2, the total number of Zooplankton varied from 825 to 1232nos/ m^3 in February and March respectively (Table-15). Maximum of Copepods were observed in May and minimum exhibited in April and January; and the mean count was157nos/ m^3. The population ranged from 140 to 210nos/ m^3. Amphipods showed a constant density of 100nos/ m^3 in all the months except in February and March where the population was nil and 180nos/ m^3 respectively. The minimum and maximum of decapods were 200nos/ m^3 in February and 310nos/ m^3 in March respectively. Cladocera exhibited a maximum density of 250nos/ m^3 in May and a minimum of 100nos/ m^3 in January, March and April. Polychaetes showed considerable fluctuations ranging from 180 to 280nos/m^3 in April, May and January

Species	January	February	March	April	May	June
Copepods	110	82	73	100	210	140
Amphipods	0	0	100	74	100	100
Decapods	160	78	200	180	160	100
Mysids	0	0	0	0	100	0
Brachyura	0	0	0	100	0	0
Tanaids	0	0	0	0	0	0
Cladocera	180	210	114	160	210	160
Fish larvae	0	0	100	0	0	0
Fish eggs	0	0	0	0	0	0
Polychaetes	240	180	280	110	82	240
Total	690	550	867	724	862	740

Table-16. Station 3 Zooplankton nos/m^3

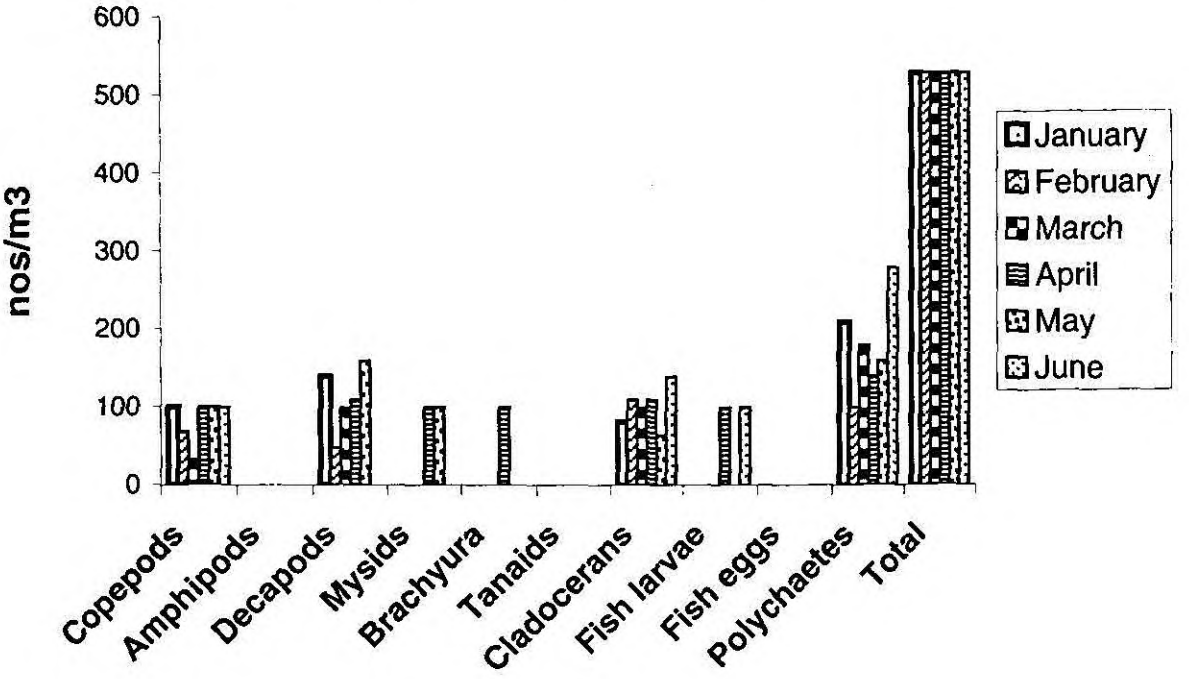
Figure-27.Station 3 Zooplankton



Species	January	February	March	April	May	June
Copepods	100	68	33	100	100	100
Amphipods	0	0	0	0	0	0
Decapods	140	48	100	110	160	0
Mysids	0	0	0	100	100	0
Brachyura	0	0	0	100	0	0
Tanaids	0	0	0	0	0	0
Cladocera	82	110	100	110	64	140
Fish larvae	0	0	0	100	0	100
Fish eggs	0	0	0	0	0	0
Polychaetes	210	100	180	140	160	280
Total	532	316	413	760	584	620

Table-17.Station 4 Zooplankton nos/m^3

Figure-28.Station 4 Zooplankton



respectively. Other sporadic occurring groups such as Mysids, Tanaids, Fish larvae and Fish eggs showed a maximum of 100nos/ m^3 during the period of investigation.

The total zooplankton of Station-3 varied from 550nos/ m^3 to 867nos/ m^3 in February and March respectively (Table-16). Highest and lowest density of Copepods was recorded in March and May with 73nos/m^3 and 110nos/m^3 respectively. Amphipods exhibited a constant presence of 100nos/ m^3 in March, May and June while the least count 74nos/m^3 of Amphipods was observed in April. Decapods of Station-3 varied from 78 to 200nos/ m^3 in February and March respectively. Cladocera exhibited the lowest density of 114nos/ m^3 in March and the highest concentration of 210nos/ m^3 in February and May. Polychaetes were observed in the range of 82-280nos/ m^3 in the months of May and March.

The minimum zooplankton population in Station-4 was 326nos/m^3 in February while the maximum was 760nos/ m^3 in April (Table-17). Polychaetes exhibited a higher density in Station-4 where the maximum of 280nos/ m^3 was recorded during June and minimum 100nos/ m^3 was observed in February. Decapods were absent in June and highest in May and the population exhibited variations in between 64 and 140nos/ m^3. Minimum numbers of Copepods (33nos/ m3) were encountered in March and Stable count of 100nos/ m^3 maintained in June, May, April and January. Rare occurrence of Mysids, Brachyuran larvae and Fish larvae showed a maximum density of 100nos/ m^3 in Station-4.

4.5. Macrobenthos

Very predominant Macro benthos were identified at the group level and the wet weight has shown in the Tables19-22. The common groups were Polychaetes, Gastropods, Bivalves, and Crustacean decapods. The wet weights of Polychaetes in mg/m^2 are given in the Table 19. The maximum weight was observed during in February at Station-1 and the lowest weight of 0.00732 mg/m^2 was recorded in April at Station 4. The peak biomass of Polychaetes was 0.8693 mg/m^2 during the study period. Polychaetes weight of Station-1 varied in between 0.1092 mg/m^2 and 0.8693 mg/m^2 in January and February respectively. In Station-2 the maximum weight of 0.12631 mg/m^2 and the minimum weight of 0.00913mg/m^2 were obtained in

Species	January	February	March	April	May	June
Actinarians	-	-	*	*	*	*
Tanaids	-	-	*	*	-	-
Halobetes	*	-	-	*	-	-
Aplysia	-	-	-	*	-	-
Flatfish larvae	*	*	-	*	*	-

Tab: 18- Rare Occurrence in the study area

Macrobenthos profile

Stations	January	Februar y	March	April	May	June
Station 1	0.1092	0.8693	0.2632	0.12856	0.6349	0.7100
Station 2	0.00913	0.12314	0.1243	0.12631	0.0933	0.1072
Station 3	0.19842	0.1851	0.14907	0.1126	0.1337	0.2152
Station 4	0.2014	0.0931	0.1282	0.00732	0.1832	0.188

Tab:19- Polychaetes (mg/m^2)

Stations	January	Februar y	March	April	May	June
Station 1	0.1973	0.2713	0.017	0.0098	0.1879	0.1161
Station 2	0.0164	0.0049	0.0032	0.00432	0.0118	0.0189
Station 3	0	0	0.007	0	0	0.0024
Station 4	0	0	0	0	0	0

Tab: 20- Gastropods (mg/m^2)

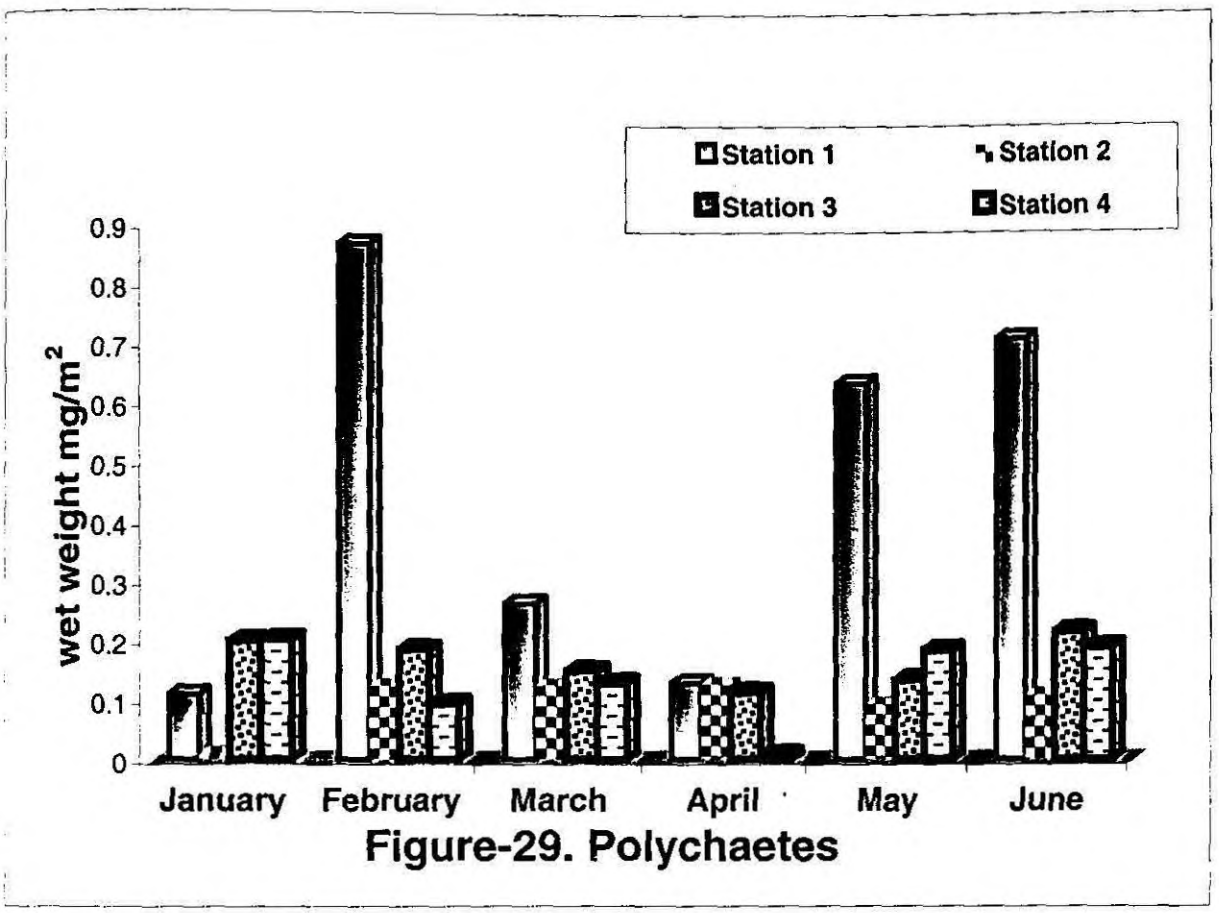


Figure-29. Polychaetes

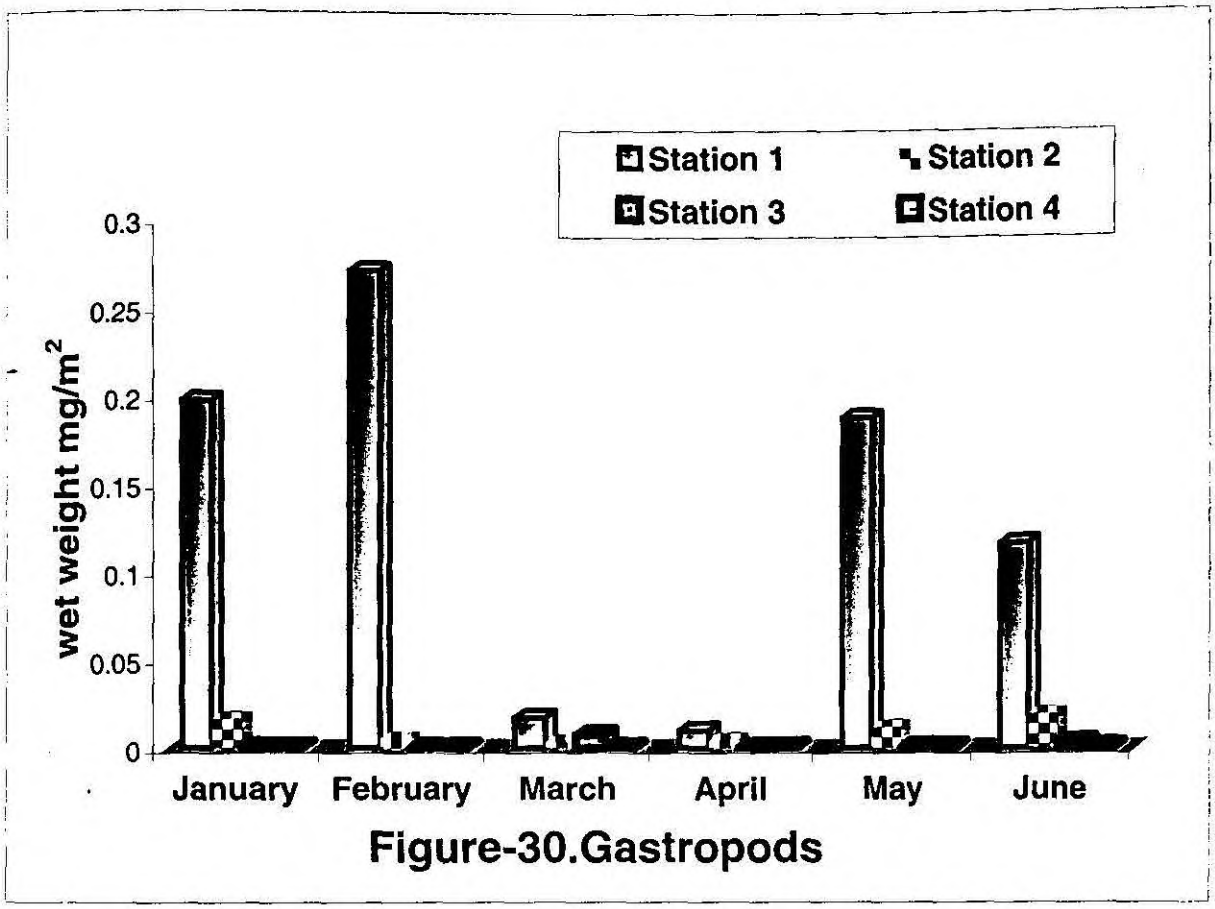


Figure-30.Gastropods

Stations	January	Februar y	March	April	May	June
Station 1	1.113	0.412	0.6294	0.6014	0.8217	0.765
Station 2	0.1946	0.0631	0	0.1329	0.0973	0.1141
Station 3	0	0.00965	0.0242	0.04763	0.137	0.0981
Station 4	0	0	0	0.0013	0	0

Tab: 21- Bivalves (mg/m^2)

Stations	January	Februar y	March	April	May	June
Station 1	0.0432	0.1275	0.0539	0.0462	0.325	0.114
Station 2	0.0013	0	0.0349	0.0041	0.081	0.0097
Station 3	0.0041	0.0101	0.01931	0	0.0219	0
Station 4	0	0	0.014	0.0031	0.0114	0

Tab: 22- Crustacean decapods (mg/m^2)

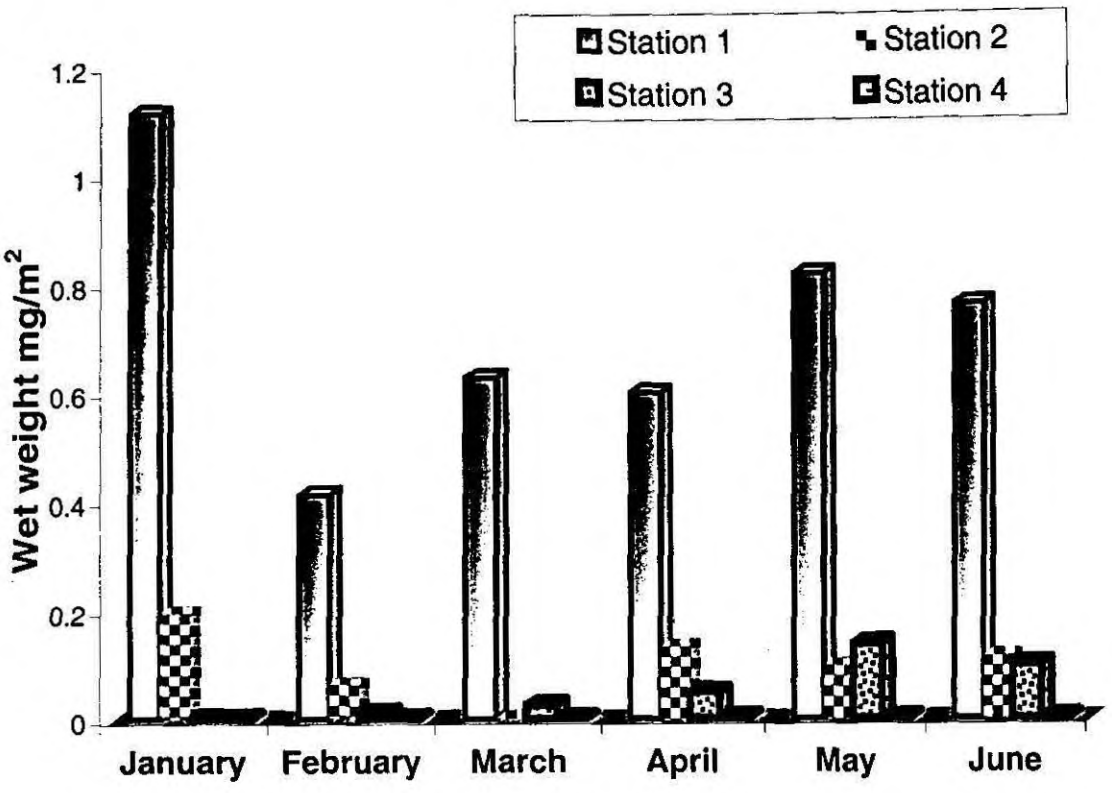


Figure-31.Bivalves

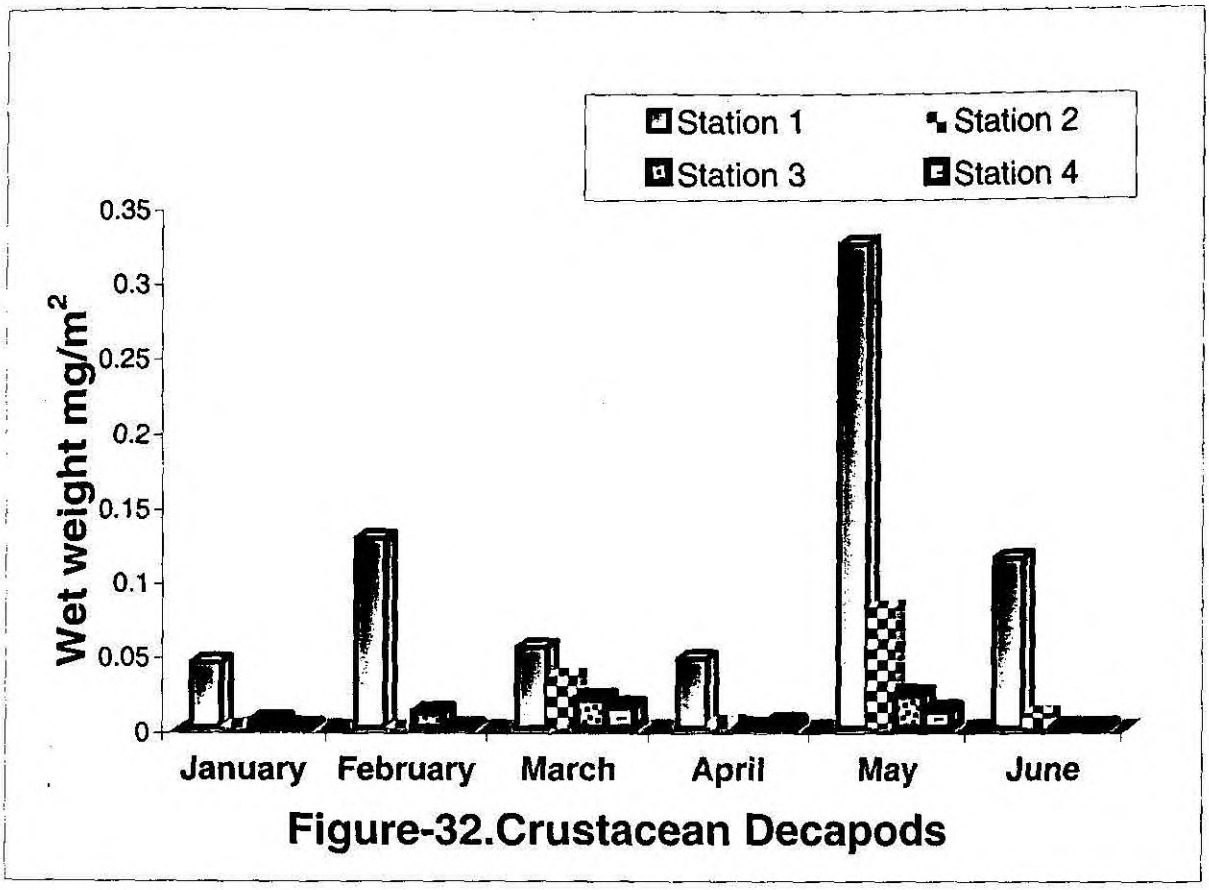


Figure-32.Crustacean Decapods

January and April respectively. The highest value of 0.2152 mg/m^2 was recorded at Station-3 during June and the lowest weight of 0.1126 mg/m^2 was observed in April. In Station-4, the minimum biomass of 0.00732 mg/m^2 was detected in April and the maximum of 0.2014 mg/m^2 was noted in January.

The highest wet weight of Gastropods were observed a reliable quantity in Station 1 and Station-2 where a highest value of 0.2713 mg/m^2 was recorded in February at Station-1 (Table-20), and the values were ranging from 0.0017 mg/m^2 in March to 0.2713 mg/m^2 in February. A mean wet weight was 0.00992 mg/m^3 during the period of investigation.

The maximum quantity of Bivalves of the four stations was observed during the month of January in Station-1 (Table-21). The values varied in between 0.412 mg/m^2 and 1.113 mg/m^2, which were obtained in February and January respectively. Bivalve's wet weight of Station-2 fluctuated in between 0.0 to 0.1946 mg/m^2, which was the maximum value noted in January. In Station-3 the lowest and highest wet weight of bivalves were 0.0 and 0.137 mg/m^2 during April and January. Bivalves were absent in Station-4 except in April with the wet weight of 0.0013 mg/m^2.

The wet weight of Crustacean decapods in Study area are represented in Table-23. The maximum quantity of 0.325 mg/m^2 in May was recorded at Station-1, while the mean and lowest wet weights were 0.1183 mg/m^2 and 0.0432 mg/m^2, obtained in January. A maximum of 0.081 mg/m^2 in May and in February decapods were absent in Station-2. The average weight was 0.022 mg/m^2 during the study period. The maximum value of Decapods in Station-3 was found to be 0.01931 mg/m^2 in March where as the average quantity recorded was 0.015385mg/m^2. The highest wet weight value of 0.014mg/m^2 was noted in Station-4 during March and the crustacean decapods were absent in months of January, February and June.

4.6.Fin fish

The qualitative study of the Manglavanam mangrove area ichthyofauna was done. The very common fish species commercially caught by the fishermen are

listed below. The size of the fish ranged from 10 to 15cm in length caught by the type of small drag net during the low tide and the set gill net operated in the Station-1 and 2.

1. *Chanos chanos* (Milk fish)
2. *Liza parsia* (Grey mullets)
3. *L. tade*
4. *L. macrolepis*
5. *Mugil cephalus*[**]
6. *Etroplus suratensis* (Peral spot)
7. *Silago sigama* (Sand whitting)
8. *Lates calcarifer*[**] (Sea bass)
9. *Siganus canaliculatus*[**] (Rabbit fish)
10. *Epinephelus*[**] *spp.* (Grouper)
11. *Lutjanus*[*] (Red snapper)
12. *Lethrinus*[*] (Sea bream)

* Indicates rare occurrence

** Indicates very rare occurrence

4.7. Crustaceans

Mangalavanam is a prime refuge for burrowing shy animals such as estuarine Crabs and shrimps. The area is also a conducive environment for Crustaceans since its shallowness, rich in silt, and nutrients. The dominant crustacean groups are listed below

4.7.1. Crab

1. *Ocypoda spp.*
2. *Uca spp.*
3. *Sesarma spp.*
4. *Metaplex spp.*
5. *Scylla spp.*

4.7.2. Shrimps

1.Penaeus indicus

2. *P. monodon*

3. *Metapenaeus affinis*

4. *M. brevicornis*

5. *M. dobsoni*

6. *Acetes indicus*

7. *Macrobrachium spp.*

4.8. Bivalves

Bivalves were rare in this mangrove ecosystem.

4.9. Macrovegetation

True mangrove plants dominated the macrovegetation of Mangalavanam. Prominent species found in this area are listed

1. *Avicennia marina*

2. *Rhizophora mucronata*

3. *Acanthus ilicifolius*

The some associated littoral species which enriched the Mangalavanam plant diversity, are

1. *Tectoma grandis*

2. *Mangifera indica*

3. *Swietenia macrophylla*

4. *Artocarpus hirsute*

5. *Hydnocarpus laurifolia*

6. *Artocarpus heterophyllus*

4.10. Avian fauna

Avian fauna found in the Mangalavanam was dominated by little cormorant, Black crowned night heron and some egret species. The name of the birds are listed below

Common Name	Biological Name
1. Little cormorant	- *Phalactocorax niger*
2. Black crowned night heron	- *Nycticorax nycticorax*
3. Little egret	- *Egretta garzetta*
4. Great egret	- *Casmerodjus alba*
5. Columbidae	- *Columbia fivia*
6. Centropodidae	- *Centropus sinensis*
7. Cuculidae	- *Eudynamus scobpaces*
8. White throated kinfisher	- *Halcyon smymensis*
9. House crow	- *Corvius splendens*

4.11.Other minor Biota

1. Indian flying Fox	- *Pteropus giganteus*
2. Painted bat	- *Kerivoula picta*
3. Striped palm squirrel	- *Funambhulus palmarum*
4. House rat	- *Rattus rattus*
5. Bandicoot rat	- *Bandicola spp.*
6. Common rat snake	- *Pyras mucosus*

4.12. Statistical indices

4.12.1. Richness indices

Phytoplankton Indices of richness, evenness and diversity are given in Tables 23-26. Richness indices of Station-1 showed a maximum value in month of May subsequently a minimum value stabilized in the months of February, March and June where as the moderate values were exhibited in January and April. The indices of richness (R1) fluctuated in between 0.51092 and 0.75276. Station-2 exhibited least richness during February and the stable values observed in January, March and April where as the peak values were noted in the months of May and June. The values of Station-2 ranged from 0.35524 to 0.75818. Highest richness indices of Station-3

Months	λ	H'	R1	R2	E1	E2	E3	E4	E5
January	0.13377	0.87114	0.595794	0.022481	0.41893	0.298704	0.198519	3.128311	4.659875
February	0.14082	1.9062	0.515538	0.020791	0.979593	0.961068	0.954579	1.055561	1.065262
March	0.15191	1.9126	0.515254	0.020724	0.982882	0.967239	0.961778	0.972259	0.967452
April	0.140264	1.6916	0.595099	0.022328	0.813488	0.67852	0.632594	1.313413	1.38419
May	0.10853	2.02558	0.752763	0.025339	0.879698	0.758051	0.731167	1.215492	1.248239
June	0.148364	1.43856	0.510922	0.019726	0.739274	0.602089	0.53577	1.599237	1.785647

Table-23.Statistical indices of Phytoplankton-Station1.

Months	λ	H'	R1	R2	E1	E2	E3	E4	E5
January	0.132	2.05184	0.606547	0.024949	0.986726	0.972776	0.968887	0.973472	0.96956
February	0.2109	1.581103	0.355237	0.017942	0.982395	0.972063	0.965078	0.975572	0.969243
March	0.13269	2.0492	0.605918	0.0248	0.985457	0.970211	0.965956	0.970969	0.966676
April	0.11625	1.9432	0.682356	0.025609	0.884388	0.775673	0.747632	1.232214	1.271038
May	0.111967	1.7572	0.753823	0.025553	0.763142	0.579619	0.532909	1.540876	1.653648
June	0.1096	2.5758	0.758176	0.026444	1.118656	1.314183	1.349092	0.694279	0.669099

Table-24.Statistical indices of Phytoplankton-Station 2.

Months	λ	H'	R1	R2	E1	E2	E3	E4	E5
January	0.09775	2.3615	0.839814	0.028558	0.984822	0.964259	0.960685	0.964488	0.960791
February	0.10432	2.2803	0.759844	0.026791	0.990322	0.977961	0.975513	0.980191	0.977935
March	0.09761	2.413	0.919117	0.030225	0.971063	0.930618	0.92431	0.917388	0.909263
April	0.08574	2.5492	0.993963	0.031071	0.99386	0.984374	0.983072	0.911408	0.903899
May	0.07852	2.53514	1.069566	0.032123	0.960623	0.9013	0.893707	1.009305	1.010106
June	0.14485	1.8722	0.597689	0.022904	0.900338	0.812823	0.786084	1.061684	1.072894

Table-25.Statistical indices of Phytoplankton-Station 3.

Months	λ	H'	R1	R2	E1	E2	E3	E4	E5
January	0.1304	2.0581	0.608245	0.025354	0.989737	0.978885	0.975868	0.979267	0.976231
February	0.17557	1.7653	0.440701	0.02063	0.985233	0.973888	0.968665	0.974742	0.969527
March	0.110277	2.254	0.76319	0.027496	0.9789	0.952576	0.947307	0.951953	0.946317
April	0.12057	2.1572	0.685734	0.026359	0.981784	0.960766	0.955862	0.959181	0.953843
May	0.0958	2.372	0.843358	0.029282	0.989201	0.974437	0.971881	0.973841	0.971149
June	0.18015	1.7528	0.439907	0.02042	0.978256	0.96179	0.954148	0.96191	0.953926

Table-26.Statistical indices of Phytoplankton-Station 4.

Figure-33. phytoplankton Diversity indices ' λ'

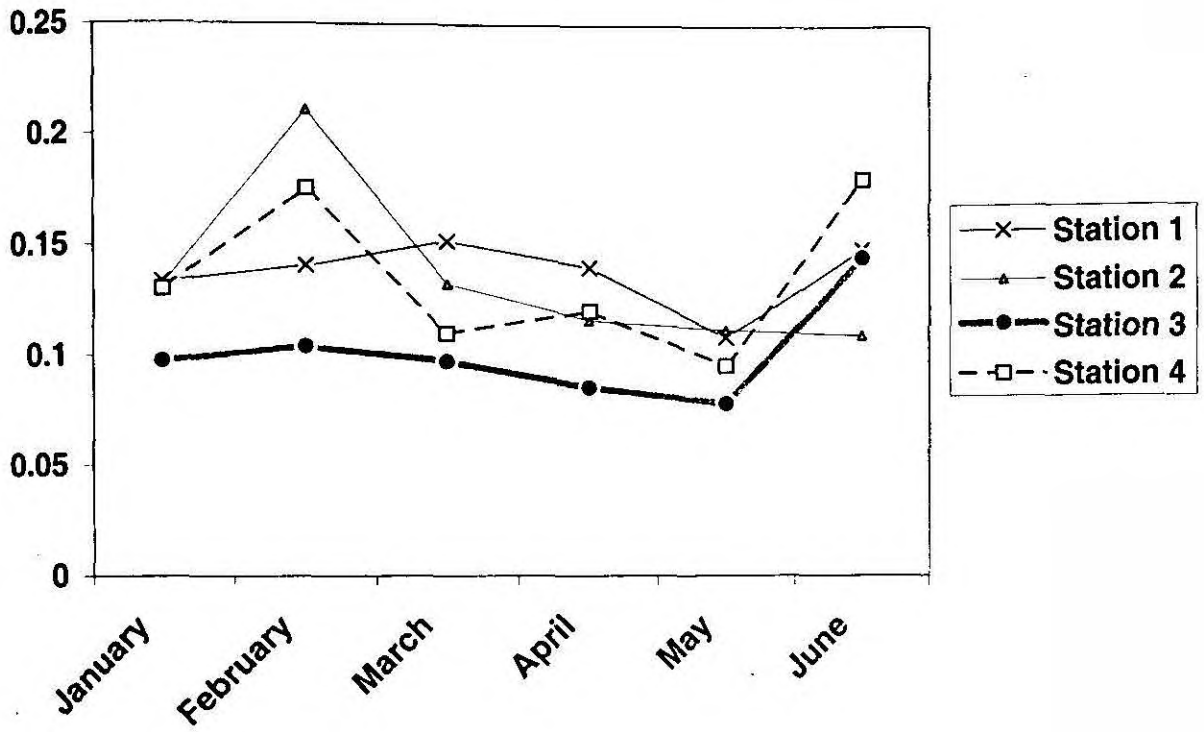


Figure-35. phytoplankton Diversity indices H'

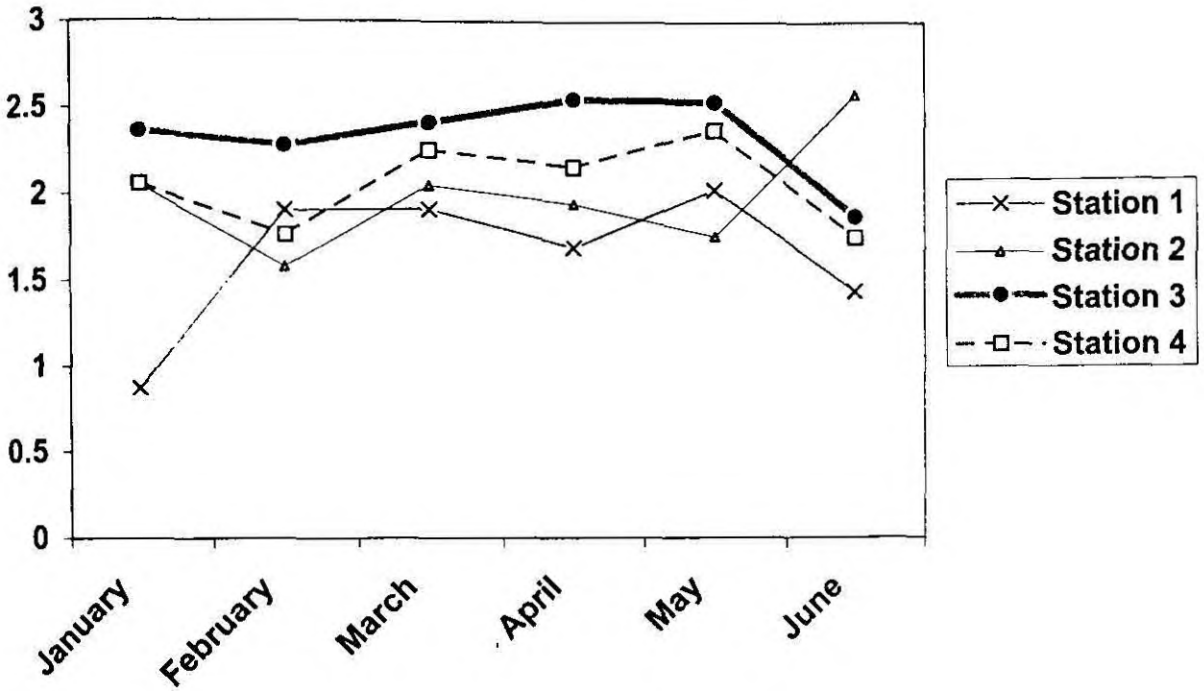


Figure- 41.phytoplankton Richness index R1

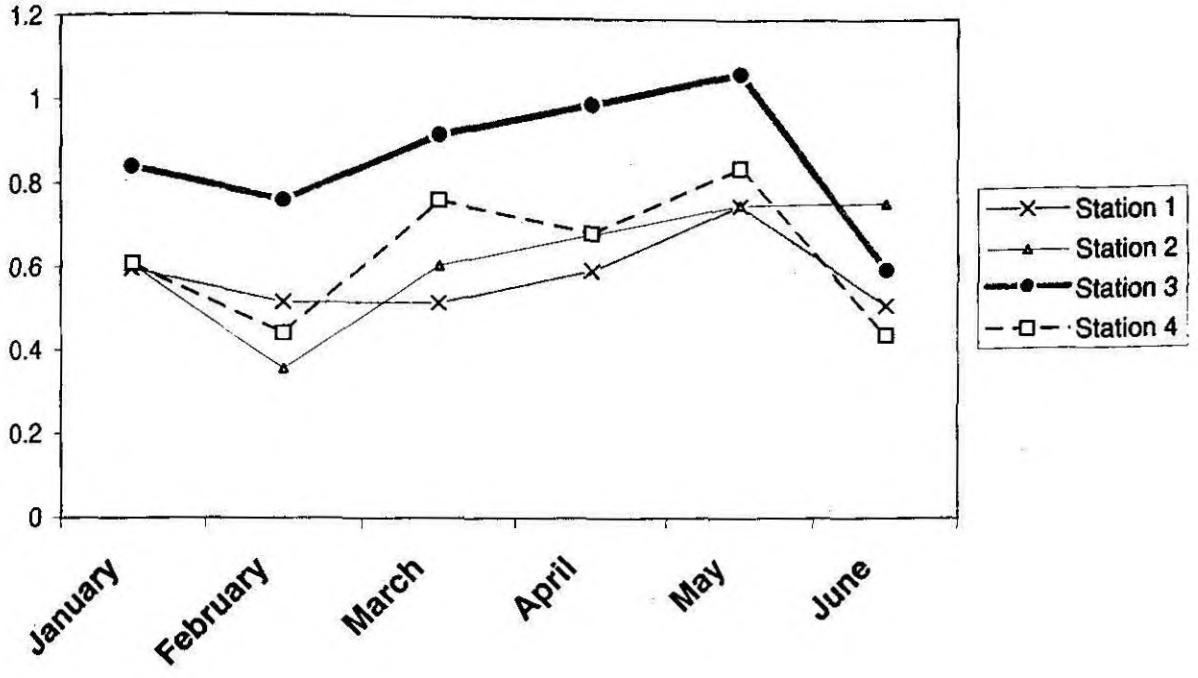
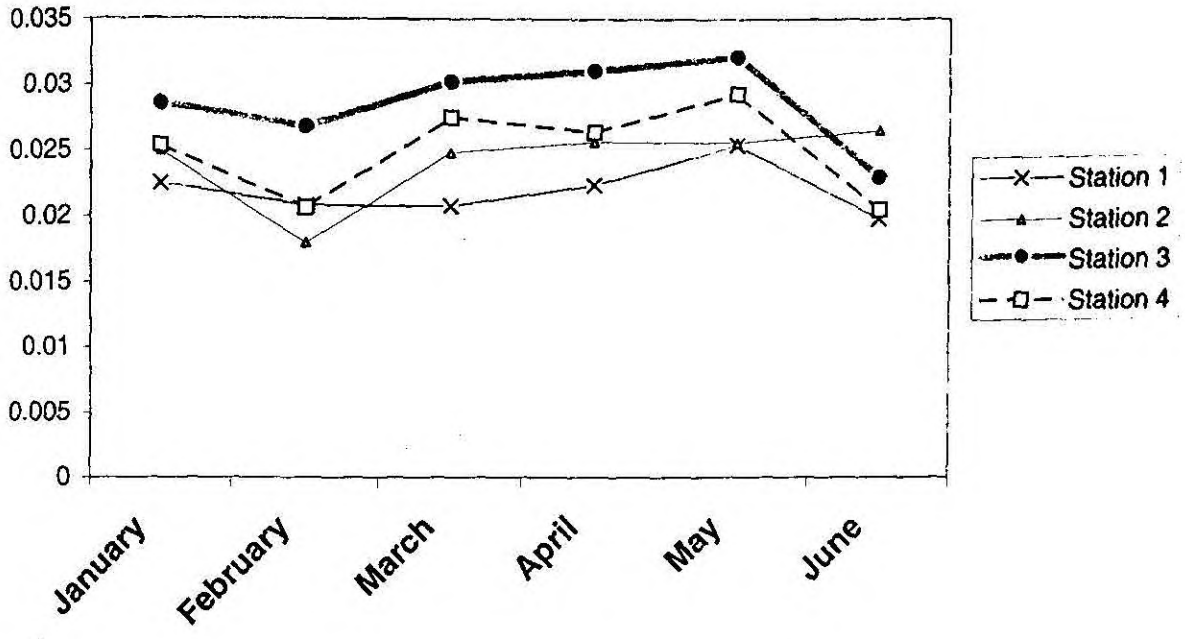


Figure- 42.phytoplankton Richness index R2



Months	λ	H'	R1	R2	E1	E2	E3	E4	E5
January	0.2213	1.549	0.596187	0.174608	0.962448	0.941352	0.92669	0.960056	0.94928
February	0.1428	1.911	0.963467	0.211554	0.918997	0.844981	0.822835	1.035941	1.042181
March	0.18846	1.722	0.717285	0.183855	0.961066	0.932618	0.919142	0.948256	0.936997
April	0.13987	1.8403	0.942943	0.195471	0.884997	0.787303	0.756918	1.135124	1.160627
May	0.16655	1.8612	0.807267	0.170276	0.956468	0.918779	0.905242	0.933569	0.921338
June	0.1933	1.71175	0.695857	0.165145	0.955346	0.923108	0.907729	0.934038	0.919505

Table-27.Statistical indices of Zooplankton-Station 1.

Months	λ	H'	R1	R2	E1	E2	E3	E4	E5
January	0.2365	1.5174	0.591985	0.170499	0.942814	0.912071	0.890088	0.927194	0.906744
February	0.2573	1.3699	0.446735	0.139262	0.988174	0.983739	0.978319	0.987689	0.983494
March	0.16991	1.857	0.843124	0.199431	0.954309	0.914928	0.900749	0.918959	0.903964
April	0.16957	1.8614	0.868589	0.221359	0.95657	0.918962	0.905456	0.916759	0.901437
May	0.19089	1.7141	0.71035	0.177705	0.956657	0.925279	0.910335	0.94361	0.931221
June	0.2295	1.5312	0.588996	0.1676	0.951388	0.924744	0.90593	0.942379	0.926478

Table-28.Statistical indices of Zooplankton-Station 2.

Months	λ	H'	R1	R2	E1	E2	E3	E4	E5
January	0.26716	1.3495	0.458948	0.152277	0.973458	0.963874	0.951832	0.970841	0.96063
February	0.29394	1.2939	0.475442	0.170561	0.933352	0.911746	0.882327	0.932841	0.907469
March	0.2076	1.677	0.739094	0.203771	0.935952	0.891581	0.869897	0.900452	0.877565
April	0.1812	1.746	0.759325	0.222988	0.974461	0.955272	0.946326	0.962861	0.955012
May	0.1882	1.724	0.739726	0.204361	0.962183	0.934485	0.921382	0.947669	0.93631
June	0.2232	1.5523	0.605451	0.183804	0.964498	0.944464	0.93058	0.948747	0.934978

Table-29.Statistical indices of Zooplankton-Station 3.

Months	λ	H'	R1	R2	E1	E2	E3	E4	E5
January	0.2828	1.3206	0.477962	0.173422	0.952612	0.936417	0.915223	0.944042	0.923661
February	0.2709	1.338	0.518413	0.22154	0.965163	0.952853	0.937138	0.968512	0.957312
March	0.3119	1.251	0.498054	0.196827	0.902406	0.873459	0.831278	0.917661	0.884644
April	0.1439	1.9386	0.904525	0.253917	0.996243	0.992717	0.991503	1.000037	1.000043
May	0.2194	1.556	0.627953	0.206901	0.966797	0.947965	0.934956	0.961615	0.951351
June	0.30585	1.2835	0.466583	0.160644	0.92585	0.902313	0.86975	0.905888	0.86982

Table-30.Statistical indices of Zooplankton-Station 4.

Figure-34. Zooplankton Diversity indices 'λ'

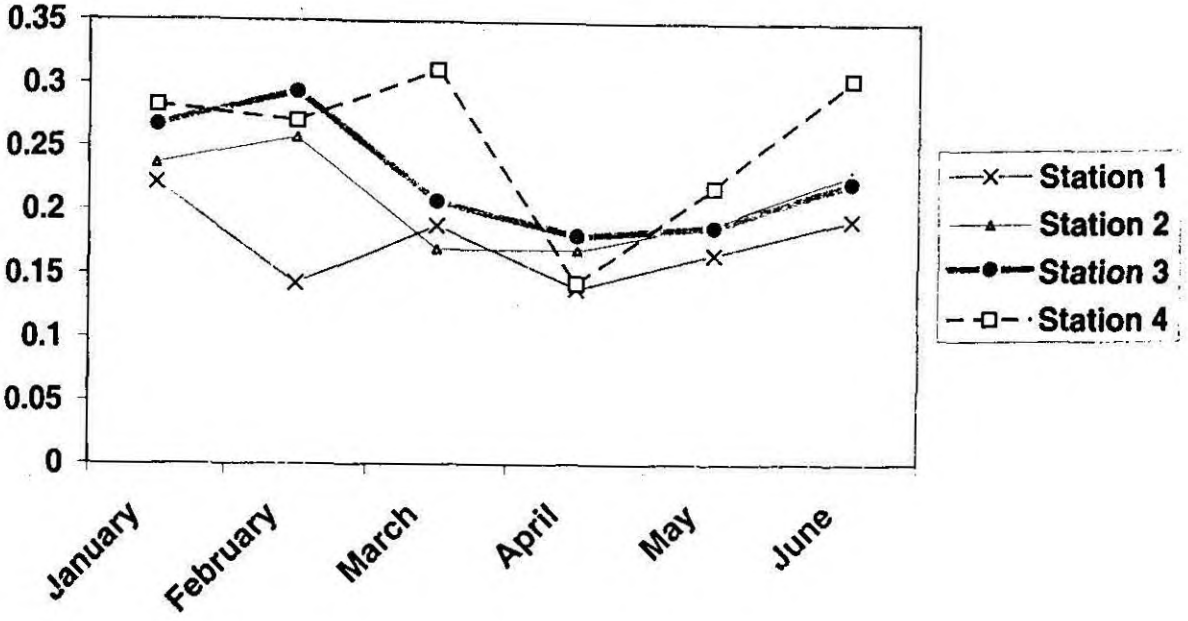


Figure-36. Zooplankton Diversity indices H'.

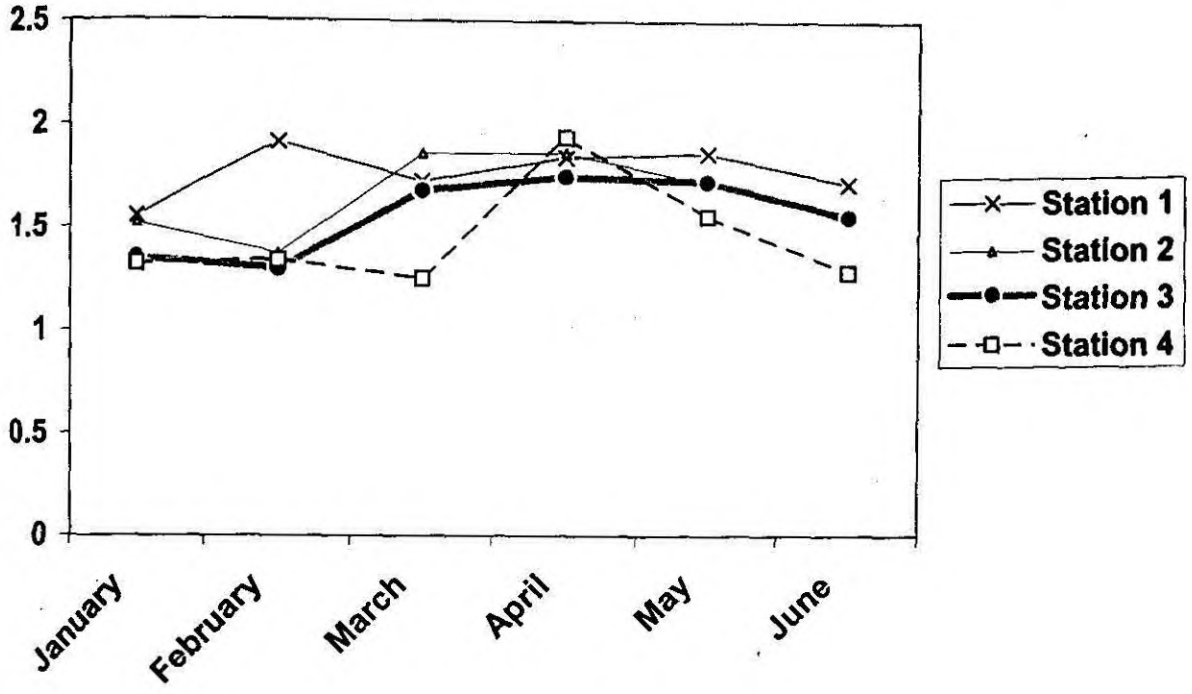


Figure-43. Zooplankton Richness index R1

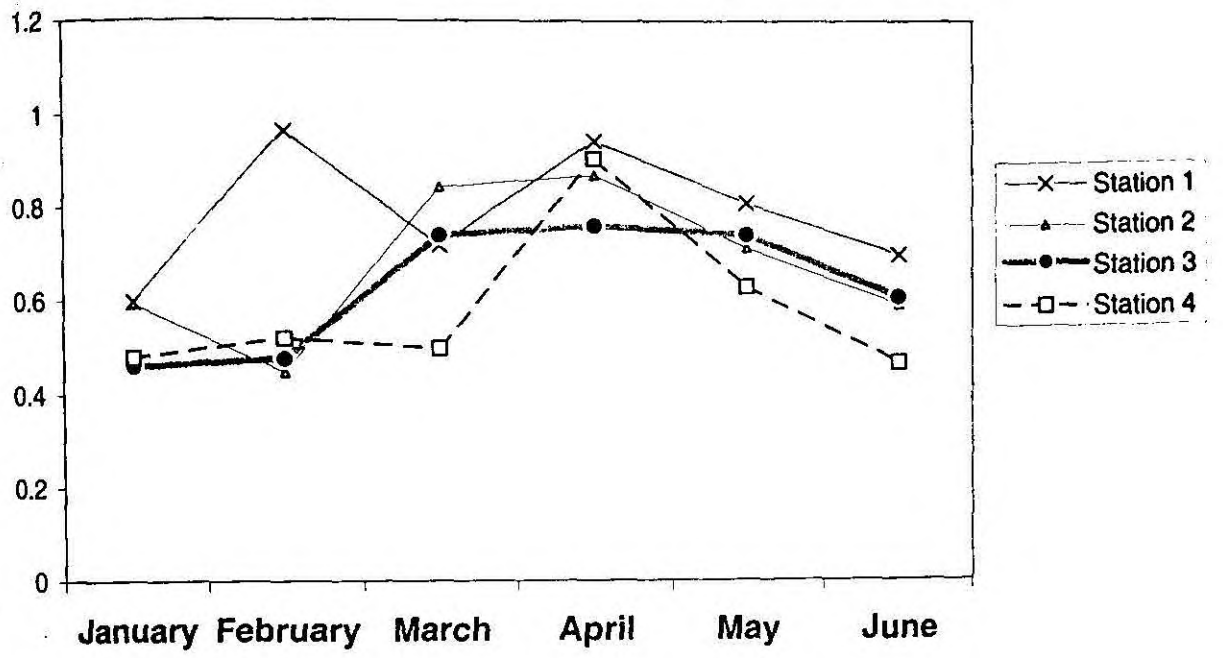
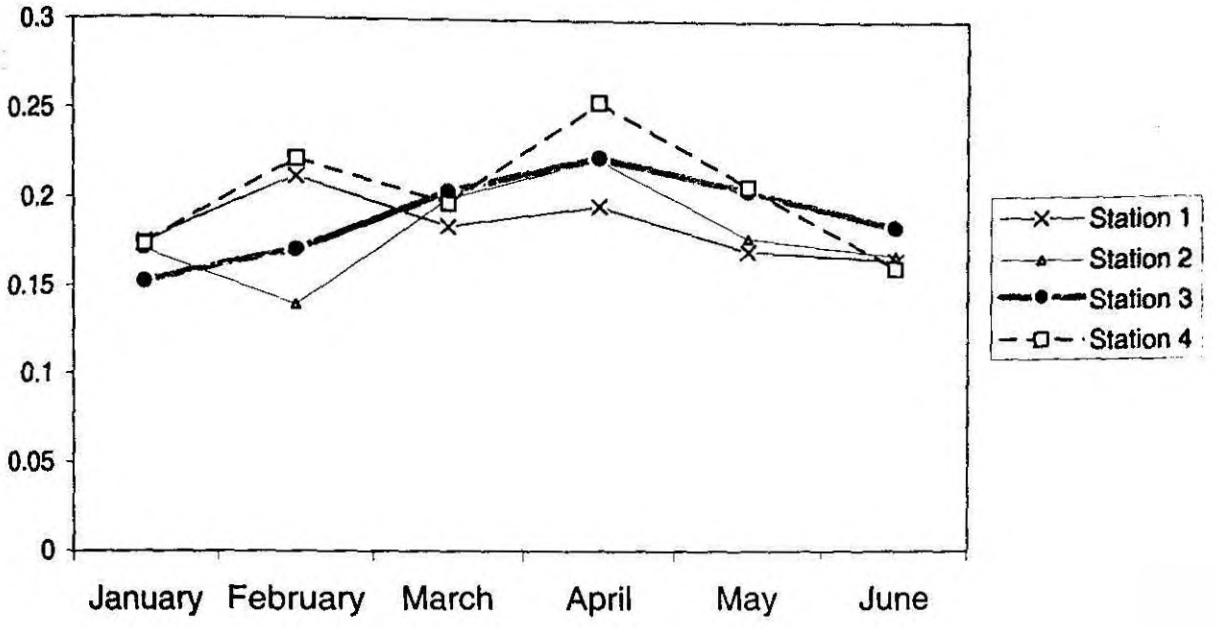


Figure-44. Zooplankton Richness index R2



acquired in May and the least obtained in June while the constant values were shown in March, April and January. The index of richness in Station-3 was highly fluctuating between 0.59769 and 1.06957. Richness indices of Station-4 were found to be maximum in May and minimum during June while the values varied from 0.43991 to 0.84336. Comparatively index of richness were highest in Station-3.

Zooplankton richness of Station 1 reached a peak value of 0.8686 during February and the least value of 0.4467 showed in January (Table 27-30). Moderate rise and fall in values were noticed in the subsequent months. Station-2 observed a highest value of 0.86859 in April and a lowest value of 0.4467 in February. Maximum value of richness indices was in April in Station-3 and a minimum richness in January while the values were varied in between 0.4589 and 0.75933. Comparatively richness values were highest in April in Station-4 while the lowest projected at the end of study period where the values ranged from 0.46658 to 0.9045.

4.12.2. Evenness indices

The table 23-26 shows the five indices worked out on evenness. E_1, E_2, E_3 are sensitive to species richness where as E_4 & E_5 relatively unaffected by species richness and hence are tend to be independent of sample size. E_4 & E_5 are conveniently used for the assessment of uniform distribution. In Station-1 evenness indices of phytoplankton showed a peak value of 3.128 in January where as it was found to be low during March. Evenness index of Station-2 was observed maximum value in April with 1.540878 and a minimum distribution noticed during June. In Station 3 evenness indexes attained the maximum value of 1.01684 during June and the minimum observed in January. In general, Station 4 exhibited highest phytoplankton evenness values in January and lowest index noted in June.

With regard to Zooplankton in Station-1, the maximum evenness of 1.131 was observed in April. Station-2 evenness index attained the peak value during February while the value recorded as 0.987. Station-3 showed the highest evenness in January where the value was 0.9708. Station-4 showed good evenness distribution with highest value of 1.0037 in April.

Stations	January	February	March	April	May	June
Station 1	7.475518	7.101264	6.582845	7.129413	9.214042	6.74018
Station 2	7.575758	4.741584	7.536363	8.602151	8.931203	9.124088
Station 3	10.23018	9.58589	10.24485	11.66317	12.73561	6.903693
Station 4	7.668712	5.695734	9.068074	8.293937	10.43841	5.55093

Table-31.Phytoplankton Diversity index 'N_2'

Stations	January	February	March	April	May	June
Station 1	2.389633	6.727476	6.77067	5.428159	7.580506	4.214622
Station 2	7.782207	4.860314	7.761689	6.981055	5.796185	13.14183
Station 3	10.60685	9.779614	11.16741	12.79686	12.6182	6.502586
Station 4	7.831077	5.843325	9.525763	8.646892	10.71881	5.770738

Table-32. Phytoplankton diversity index 'N_1'

Figure- 37.phytoplankton Diversity index N2

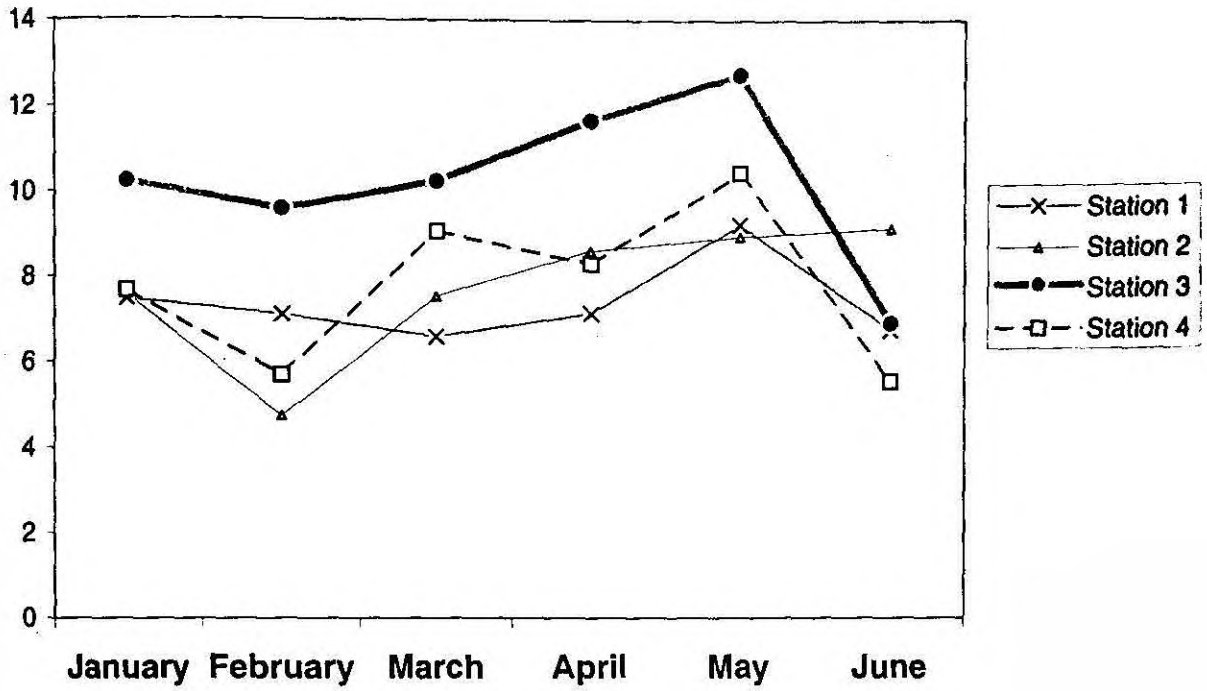


Figure- 38.Phytoplankton Diversity index N1

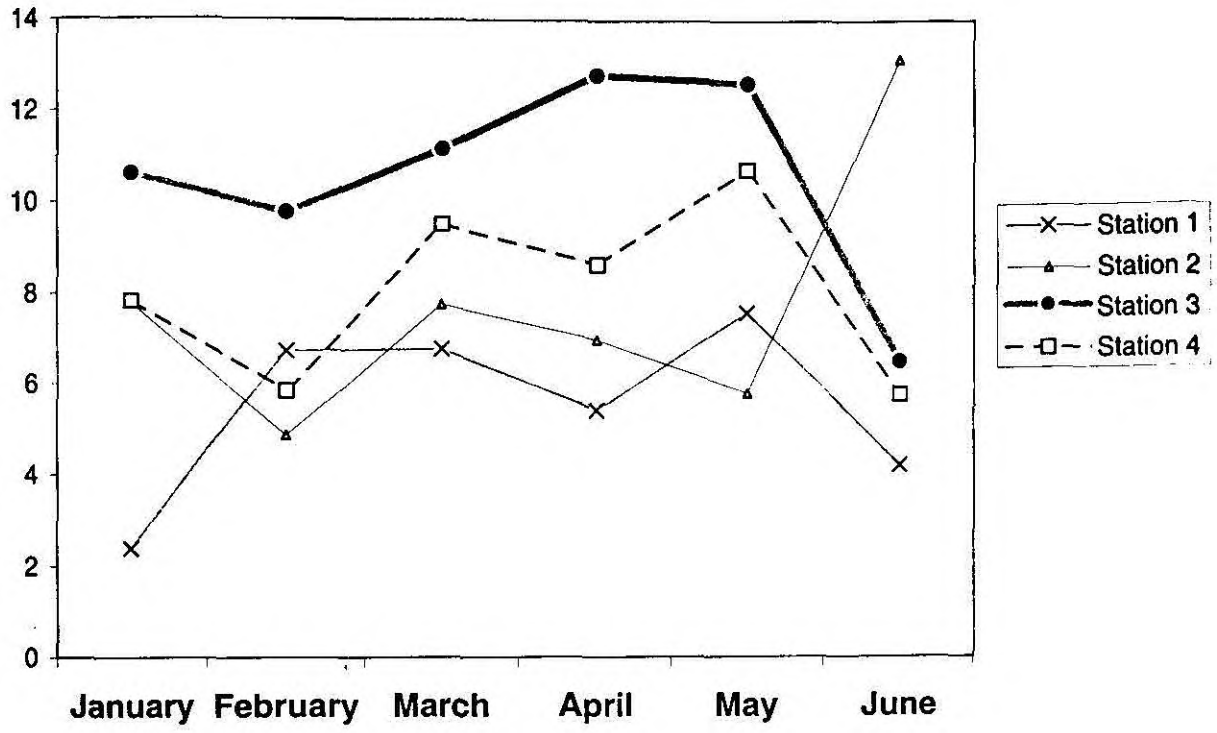


Figure- 39.Zooplankton Diversity index N2

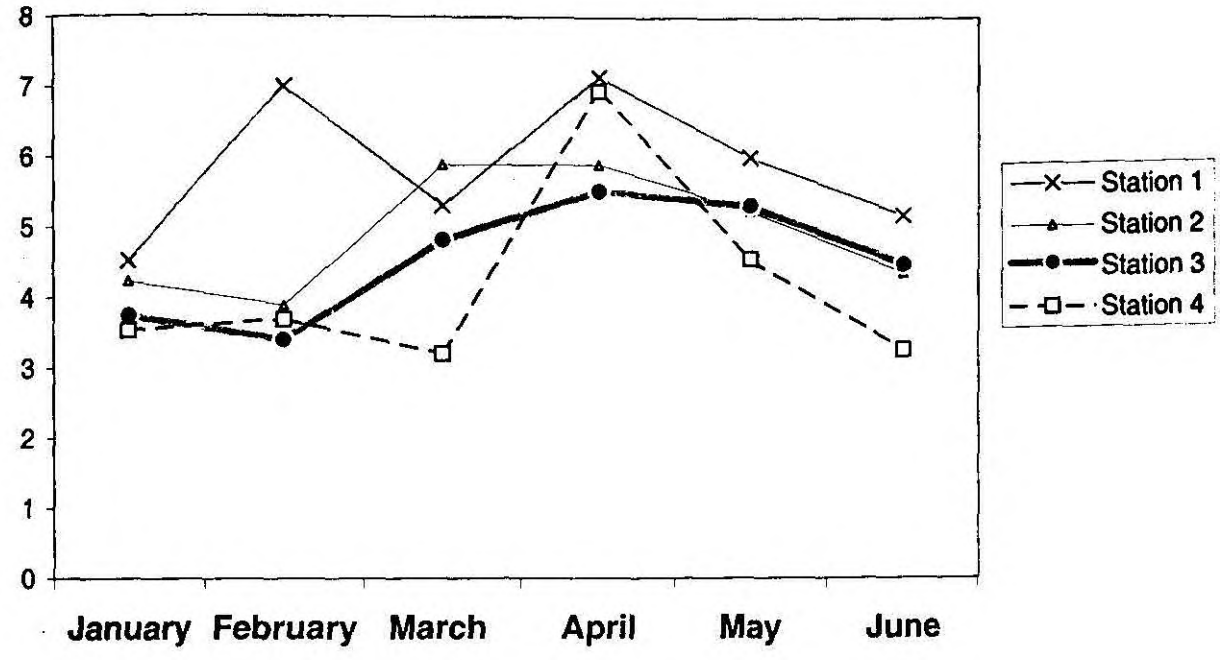
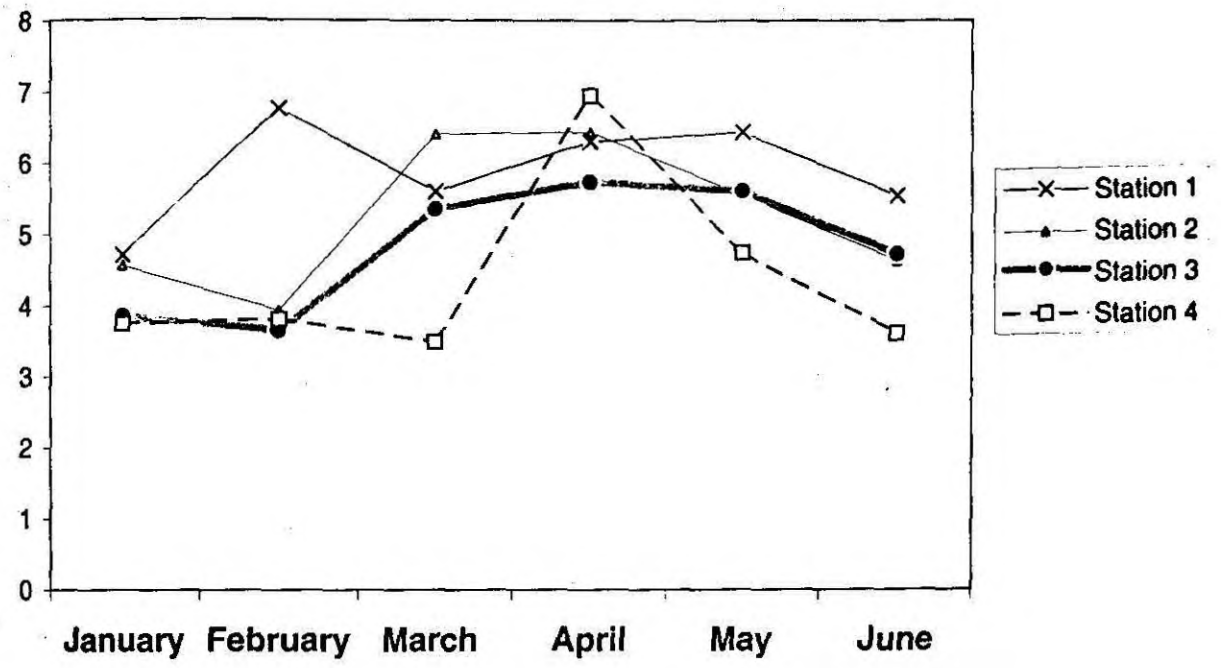


Figure-40.Zooplankton Diversity index N1



4.12.3. Diversity indices

Diversity indices, which helps to derive the effective number of species, is indeed a measure of the degree to which species proportionally distributed abundantly. Explicitly N_2 is the number of very abundant species and N_1 is the number of abundant species in the sample. N_1 will always be intermediate between N_0 and N_2. The effective number of each species is a measure of the number of species in the sample, where each species is weighed by its abundance. N_1 and N_2 are suitable addressing a heterogeneity index (Peet, 1974). These were listed in the Table 31-34.

The N_2 values for Phytoplankton of Station-1 were fluctuating between 6.58285 in March and 9.214 in May. Station-2 exhibited the least value of 4.7415 in February and 9.1241 in June that being regarded as the peak value. Comparatively higher N_2 values observed in Station-3; in the month of May implicit the highest N_2 value of 12.74, and the lowest N_2 value of 6.904 recorded in June. Likewise Station 4 also showed the maximum N_2 value of 10.438 in May and the minimum N_2 value of 5.551 in June.

The N_1 value of Hill's number express that those of abundant species in the sample area. N_1 always lies between N_2 and N_0 (the number of all species). In Station-1, the N_1 values were very low in January, that was 2.896 and very high values were observed in May while the values were in the range of 2.3896-7.581. In Station-2 the highest value of 13.142 was in June while the lowest value of 4.861 was in February. The peak value of 12.79686 was observed in April in the Station-3 where the least value was noted in June, which was 6.503. The same trend of fluctuation was exhibited in Station-4 where the values were ranging from 5.771 to 10.71881.

In the case of zooplankton, the N_2 values were fluctuating widely in between 3.206 and 7.14, which were calculated in March at Station-4 and in April at Station-1. The diversification of zooplankton in Station-2 was showed the minimum value particularly in February. Similar pattern of fluctuation was observed in Station-3 also, where the values ranged from 3.402 to 5.518. Lower values often obtained in

Station-4 in which the minimum N_2 value of 3.206 was recorded in March and the maximum N_2 value of 6.95 was observed in April.

N_1 values of zooplankton were in the range of 3.647-6.7598 in general, the highest value of abundance (N_1), 6.759 was obtained was obtained in February and the lowest N_1 value of Station-2 were fluctuating between 3.934 and 6.433 during February and April respectively. The maximum and minimum N_1 value of abundance were 5.73 and 3.64 in April and February respectively at Station-3. Station-4 exhibited the peak N_1 value of 6.94 in April and the least value of 3.493 in March.

5.DISCUSSION

5.Discussion

The conservative and non-conservative parameters studied, were exhibiting significant variations among the stations. According to Jayson (1999), the study area Mangalavanam located in Kerala is influenced by two distinct seasons, which are the monsoon starting from end of May up to the middle of November and the dry summer, from December to the first half of May. There is no clear marked winter season. Rainfall varies from 4mm in March to 676mm in June. More over Mangalavanam is being located in the main land there appears to have greater influence of land runoff (Shajina, 1992).

5.1.Water parameters

5.1.1.Temperature

The major impacts on Mangrove are likely to be caused by increasing temperature, changing hydrologic regimes such as rainfall, evapotranspiration, runoff and salinity and rising relative sea level, due to a combination of factors (Kjerfve *et al.* 1997). The average global temperature has only increased by 0.5^{0}C in response to a combination of green house warming and a rebound from the little ice age (Stewart *et al.* 1990). The present latitude observed a higher water temperature during initial periods but the temperature decreased towards the end of study period (May-June), which is attributed to the onset of monsoon climatic changes and freshwater influx. The importance of favourable temperature for the establishment and development of mangroves have been emphasized by Macnae (1968) and Chapman (1977) Mangrove cannot tolerate temperature less than 20^{0}C for a continuous period. Therefore the mangrove formations are only found in the tropical and subtropical coasts of the world. (Untawale, 1987). The water temperatures observed by the previous researchers from different mangrove areas of India include that of Untawale *et al.* (1973) and Shanmugam *et al.* (1986). The temperature in the Cochin area have been affected by southwest monsoon and the similar range of results have been obtained by various workers such as Rajagopalan *et al.* (1986) and Sunilkumar

(1993). The distribution of fish molluscs and crustaceans would adjust rapidly to any temperature increase caused by climatic change with in mangroves, soft bodied animals and bivalves would be highly sensitive to temperature rise, where as many species of mangrove crabs and gastropod snails could possibly accommodate a hotter environment provided they had access to water to replenish water lost by evaporation, respiration and feeding (Kjerfve, 1997). In the present investigation remarkable variation in the distribution of general biota could not be observed due to climatic changes.

5.1.2. pH

Mangrove ecosystem in general exhibits a lower pH concentration when compare to other tropical backwater ecosystem. The lower pH is attributed to a group of factors such as photosynthesis, litterfall, influx of rainwater, tidal influence and species diversification (Bird & animals). The fluctuation of pH of Cochin mangrove was studied by Silas and Pillai (1975); Nair *et al.* (1975); Pillai (1975) and Sunilkumar (1993). In the present study higher pH was detected in mangroves during post monsoon period while it was very low during the onset of southwest monsoon due to the considerable dilution with freshwater. According to Silas and Pillai, (loc. Cit) and Nair *et al,* (loc.cit), higher pH in mangroves due to the increased saline condition and the excessive photosynthetic activity of the algae that might have resulted in the depletion of the amount of CO_2 content which lead to the increase of the pH in the water. Lower pH often detected in the Station-3 was attributed to the enormous droppings of rich avian fauna and high litter in that particular Station.

5.1.3. Salinity

Variations in salinity as a result of climatic change most likely to cause shifts in the relative distribution of species with in those taxa occupying a halocline. However euryhaline mangrove animals are affected marginally. In mangrove ecosystems, where extreme and fluctuating high water temperatures and salinity are characteristic, euryhaline and eurythermal animals like shrimps, crabs and certain fishes such as mullets and seabass will proliferate (Kjerfve *et al.* 1997). Salinity found to be the most fluctuating factor. The pattern of salinity distribution in the area was considerably influenced by surface freshwater influx and rainfall. Most of the time in

the period of study, brackishwater condition prevailed in the area. Peak salinity values were observed during April and may, while the Cochin area was dry with less rainfall. Among the sampling stations, Station-1 experienced the higher saline condition, since of its proximity to the sea. Station-4 is often exhibited less salinity owing to the discharge of freshwater dominated household waste in liquid form. Marcio *et al.* (1997) opined that the mangrove salinity patterns of the mid littoral zone originate through a dynamic balance between salt concentration (evapotranspiration) and salt transport (by water fluxes and diffusion). The salinity variations in different mangrove ecosystem in India were studied by Untawale *et al.* (1973); Joshi and Jemale (1975); Untawale and Parulekar (1976); Matondkar *et al.* (1980); Kasinathan and Shanmugam (1985); Nandi and Choudhury (1983); Palaniappan and baskaran (1985); Venkatesan and Natarajan (1986); Rajagopalan (1986) Venkatesan and Natarajan (1987) and all them are almost expressed similar opinion about the salinity distribution pattern in the ecosystem which is in accordance with the present observations.

5.1.4.Dissolved Oxygen

Dissolved oxygen is one of the prime factors deciding the diversification and distribution of all aquatic organisms. Photosynthetic activity, diffusion rate from atmosphere and decomposition rate of organic matter are the major factors determining the DO level in the aquatic system where as the other supplement factors such as rainfall, temperature, salinity, tidal flux and humidity are also likely to effect directly or indirectly the DO concentration in the natural systems. Oxygen is mainly consumed on the muddy bottom surface due to the biological and chemical actions. This depletion is counteracted by mixing with surface waters in which the oxygen is not so rapidly consumed as stated by Mazda *et al.* (1990). Higher DO content was observed in Station-2, where channel is narrow and hence the adequate water circulation and mixing during high tide enhanced a rise in the DO content of the water. Generally higher DO values observed during the onset of monsoon period. According to Qasim *et al.* (1969) the higher DO is due to the higher primary production during this period and further to that high DO in freshwater brought by the rivers might have also increased the oxygen content. According to Untawale *et al.* (1973) during monsoon months, due to freshwater influx the DO content increases. The decrease in temperature may also be favourable for the increase in the DO

levels during this period. Similar results were reported by (Untawale *et al.*1973; Dwiwedi *et al.* 1975; Sundararaj and Krishnamurthy, 1975; Untawale and Parulekar, 1980; Matondkar *et al.*, 1980; Palaniappan and Baskaran, 1985; Shanmugam *et al.*,1986; Kasinathan and Shanmugam, 1985; Rajagopalan *et al.* 1986 and Sunilkumar, 1993, in different mangrove areas of India .

5.1.5. Ammoniacal Nitrogen

NH_4-N and total nitrogen are the most investigated elements in the aquatic ecosystems and nitrogen is considered as a limiting nutrient in brackishwater than in freshwater Smith (1984) and Pillai *et al.* (1962) observed that the productivity of brackishwater was directly related with the amounts of available nitrogen in bottom soil. Ammonia reaches the aquatic system as a by-product of metabolism by animal and by decomposition of organic matter by a group of bacteria and occasionally by the denitrification process of *Geobacter metallireducens* and *Desulfovibrio clostridium* (Prescott *et al.* 1996). Ammonia occurs in two forms, which are un-ionized ammonia (NH_3) and ammonium ion (NH_4^+) in a pH and temperature dependent equilibrium (Boyd, 1992). As pH rises, un-ionized ammonia increases relatively to ammonium ion. Water temperature also causes an increase in the proportion of un-ionized ammonia, but the effect of temperature is less than that of pH, which confirms the genuine fact that the present study area also acquired a linear relationship between ammonia concentration and water pH of water. However Station-3 exhibited a higher ammonium concentration probably due to the rich discharge of Uric acid by excreta of avian fauna therefore, the pH profile at this Station was also showed declining trend compared to other stations.

5.1.6. Nitrite

Nitrite in the aquatic ecosystems is an intermediate product in Nitrogen cycle by the oxidizing activity of bacteria such as *Nitrosomonas* and *Nitrococcus* in natural waters from organic and inorganic nitrogenous compounds (Prescott *et al.* 1996). Joshi (1991) also opined that Nitrite in nature originates from organic and inorganic nitrogenous compounds. According to Jhingran, (1982), many blue green algae secrete extracellular nitrogrenous compounds. Nitrite is comparatively toxic than ammonia, but the toxic effect is often nullified by the quick dynamic action of

beneficial microbes and hence this toxic substance is being quickly converted to nitrate, which is responsible for productivity. Thus the state of equilibrium is highly represent the C:N ration. In general Station-3 was rich in nitrogenous compounds but in the month of January it exhibited a very low concentration, however the ammonia concentration of this Station showed a peak value during this period of study. This regime indicates that pH shift is favouring the mineralization activity (formation of ammonia) than that of nitrification process. Which is in accordance with Boyd (1992), and is in general agreement with the findings of Joshi (1991).

5.1.7. Nitrate

Nitrate is the desiring end product of nitrogen cycle which effects the C:N ratio favourably and enhance the primary productivity. The total nitrogen and phosphorus available in a water body are the limiting factor for phytoplankton growth. The role of nitrate in soil and water investigated by several authors like Mortimer (1941); Stefansson and Richards (1963); Venkateswarulu (1969); and Mollah *et al.* (1979). Smith (1984) stated that biologists tend to favour controlling primary productivity in the brackishwater and marine environments. Nitrate is formed from nitrite through nitrification process, controlled by *Nitrobacter* and *Nitrococcus* (Prescott, 1996). The nitrate may also tend to involve in three process such as denitrification leads elementary nitrogen, assimilatory nitrate reduction produce organic nitrogen, nitrogen denitrification gives NH_3^+ (Presscott, 1996). Station-3 represents higher nitrate values during April and May, implies that higher rate of nitrification process. During June a sudden rise could be observed in Station-1 probably due to a higher discharge of sewage and surface runoff at the onset of monsoon.

5.1.8.Phosphate

The capacity of sediment to retain or release phosphorus is one of the important factors, influencing the concentrations of inorganic and organic phosphorus in the overlying water (Venkatesan *et al.* 2001). Phosphorus is one of the chief nutrients, which is functionally involved in the metabolite process of living organisms (Parson, 1975; Hakason and Janson, 1983). It reaches the mangrove environments in allogenic and attogenic pathways (Baharudeen, 1997). Phosphorus is the most

single critical factor in the maintenance of pond fertility and available in water combined with a number of ions, the more common forms being phosphates of iron and calcium. In the present investigation reveals the rich phosphorus content found in Station-3&4, was due to the avian excreta and sewage discharge. Generally poultry droppings were used as manure for increasing the phosphate content in the aquatic systems. According to FAO (1997), poultry manure contains 0.7% phosphorus that is the highest when compare to other manure regarding phosphate concentrations. This fact indeed confirms the increasing phosphate content in Station-3&4., further it has been observed increased concentration during April, May, June and January, which was attributed to mass migration of avian fauna to the mangrove system. Jayson (1999) reported that highest bird populations were observed in the above said months. Padmakumar (1983) stated that higher sewage discharge also increased the phosphorus content. It could be conveniently inferred that station 3&4 are supported with rich phosphate concentration due to the natural factor mentioned above.

5.1.9. Silicate

Among phytoplankton population diatoms require silicon for their cell wall structure formation. Boyd (1992) expressed that the general benefits of silica is unknown but experiments on silica fertilization might prove valuable information and stated that silica concentration are high in brackish water in most tropical nations. Diatoms especially silicoflagellates are rich in silica and their cell wall are chiefly composed of silica. More over shells of bivalves also contribute towards the silicate concentration in the brackish water and accordingly it can be concluded that the present study reveals that Mangalavanam is rich in silicate concentration especially in Station-1&2 since their proximity to the sea. During the premonsoon periods a shift in silicate concentration was observed probably due to the supply of silicate exceeds than its demand.

5.1.10.Chlorophyll a, b &c

Photosynthetic pigments are the index of primary production of an area and playing a significant role in the ecological characteristics of an ecosystem (Gopinathan *et al.*, 2001). Research works on chlorophyll pigments were carried out

in the west coast by researchers (Banse, 1968; Krey and Babernad, 1976; Sumitra vijayaraghavan and Krishakumari, (1989) and Balachandran *et al.* (1989, 1997) studied the distribution of chlorophyll a in the inshore waters of Cochin and Laccadive waters during monsoon. Bahia (1978) stated that pigment index values were ranging from 1.35 to 11.55 mg chl-a/m^3. Sivadasan *et al.* (1995) conducted studies on photosynthetic pigments of benthic fauna of Cochin estuary and they reported that thee chlorophyll-a concentration was ranged from 57.26mgm^{-2} (Postmonsoon) to 78.36mgm^{-2} (Premonsoon), where as the chlorophyll-b was absent oftenly and Chlorophyll-c values exhibited a fluctuation in the same trend as that of chlorophyll-a. The present findings on Chlorophyll-a, b & c are in accordance with the earlier workers. Station-3 showed higher values in all months. The Chlorophyll c values exhibited higher values in the beginning of the study period. Sivadasan *et al.* (loc.cit) opined that there was no clear variation in Chlorophyll content in between premonsoon months.

5.1.11.Transparency

Turbidity is the measure of phytoplankton bloom and suspended soil particles load in the aquatic ecosystem system where as both of this restrict light penetration in to the water (Boyd, 1992). It is a general practice of observing the light penetration by using Secchi disc, to assess the phytoplankton and suspended soil particles, thereby general turbidity. In the Station-1 a highest transparency was observed during January, which was probably due to the low algal count towards the onset of summer season. Lower values were often associated with Station-3&4 due to higher density of algae count and higher silt load. During monsoon period higher turbulence in the sea reflected in increased turbidity minimize the transparency in the system. High phytoplankton count during April and May affected the transparency in the water body.

5.2.Sediment Characteristics

5.2.1. pH

pH of the sediment in different mangrove ecosystems were studied by Joshi and Kumar,(1985); Blasco *et al.*,(1985); Mall *et al.*,(1985); and Matilal *et al.*, (1990). Sediment pH of the Kerala mangroves systems is shown lower values in the

monsoon period and the higher range in post monsoon period, (Sunilkumar 1993). In the present study it has been observed, higher values at the beginning of study investigation (post monsoon season) and the decreasing trend have been noticed in last phase of study period (pre monsoon). Higher values have been observed in Station-1 due to increased saline conditions because of the backwater proximity, whereas Station3 & 4 exhibited less pH values since the huge droppings of avian fauna, litter fall decomposition, fresh water discharge from the household and microbial activity. According to Hart, (1959) acidity of mangrove is due to the activity of bacteria on oxidizable sulphur content. Prabakaran *et al.* (1990) evaluated the phosphate solubilizing activity of fungi. The Carbon dioxide arising from decomposition of organic matter and from animal respiration also lowers the pH value of the soil as stated by Sasekumar, (1974).

5.2.2.Organic Carbon

The distribution of suspended matter in mangrove systems is controlled by a wide variety of physical, geological, chemical and biological process (Pritchard and Schubel, 1981). The principal sources of the particles in tropical coastal lagoons are mangrove litter fall, phytoplankton and river flow (Flores-verdugo 1990; Roberston ,1988; Twiley *et al.*,1986).The stations inside the mangrove ecosystem under the present study showed very high organic carbon values when compared to the other stations in the feeder channel (Station-2) and at the backwater area (Station-1), due to the abundance of finer particles which rapidly absorb the organic colloids ,derived by the increased litter fall and the excessive microbial activity. In April and May at Station-2 a sudden rise in the value observed which might have been due to higher sedimentation rate in the dry summer season. According to various authors, the association of organic carbon in the finer sediments might be due to the enhanced surface area of finer particles which in turn promotes absorbing ability of the organic colloids and also traps finer organic particles intact as reported by (Burn and Solomon, 1969; Bednarz and Strzecka, 1993; Padmalal and Seralathan, 1995). Sahoo *et al.* (1985) stated that the organic carbon in the sediments are relatively higher in surface than in sub surface which could be owing to the confinement of organic residues in these layers. In general, the variations of organic carbon observed in the mangrove environments reflect the textural control, differential hydrodynamic setup as well as the influence of various physicochemical

factors such as temperature, depth, rate of sedimentation, rate of supply of organic carbon, Eh and pH, which is in accordance with Baharudeen, (1997), who reported similar condition about the Organic carbon content in aquatic systems.

5.2.3. Ammonia

Smith (1984) and Pillay *et al.* (1962) reported that the productivity of brackishwater was directly related with the amounts of available nitrogen in bottom soil. Ammonia reaches the aquatic system as a by-product of metabolism by animal and by decomposition of organic matter by a group of bacteria and occasionally by the denitrification process of *Geobacter metallireducens* and *Desulfovibrio clostridium* as stated by Prescott *et al.* (1996). Ammonia occurs in two forms, which are un-ionized ammonia (NH_3) and ammonium ion (NH_4^+) in a pH and temperature dependent equilibrium Boyd, (loc.cit). Decomposition process usually efficiently has taken place in mangrove sediment due to its rich diversification of microbes. Present study projects that Station-1 receives a higher concentration of ammonia due to heavy dumping of domestic waste. Thus a higher shift could be observed in the ammonia concentration in Station-1 where as in April at this station increased quantity of NH_4 could be observed probably due to decomposition process in dry summer season.

5.2.4. Nitrite-N

In the nitrogen cycle, ammonia is oxidized to nitrite and nitrate by nitrification process and NO_2 -N accumulates in the aquatic environment due to its imbalance in the nitrification reaction (Sharma and Ahlert, 1977). In the present investigation it has been found that the nitrite production was almost high in Station-3 except during April where as in February and March NO_2-N was totally absent indicating decreased oxidizing process. The quantity of ammonia, nitrite and nitrate concentrations in the sediment are often available in a particular range according to the availability of organic nitrogenous compounds, nitrifying and denitrifying bacterial load, pH, salinity, and temperature. Thus the constant equilibrium state being maintained and the nutrient levels in the sediments are stabilized.

5.2.5. Nitrate-N

Venkateswarulu (1969) stated that no well-marked relationship could be observed between NO_3-N of soil and that of water. While Mollah *et al.* (1979) obtained a negative correlation between NO_3-N of soil and that of water in their studies. Nitrate production was higher in the Station 1 particularly during January, and then it kept a decreasing trend towards the onset of monsoon. The dynamic equilibrium between nitrification and denitrification process keep the nutrient balance in the soil of the system and hence how the process could be enhanced by various factors yet to clearly understood as opined by Venkateswarulu (loc.cit).

5.2.6.Phosphorus

The concentration of phosphorus in the aqueous phase is controlled by chemical equilibrium of several minerals such as $CaCo_3$-P and FeOH-P (Fabre, 1992; Pizzarro *et al.*, 1992; Froelich, 1988; Jannson, 1987; Bates & Neafus, 1980) as well as the activity of microorganisms (Patrick and Mahaphatra, 1968; Maine *et al.*, 1992). Phosphours is one of the principal nutrients, which is functionally involved in the metabolite process of living organisms (Parson, 1975; Hakanson and Janson, 1983). It reaches the mangrove environments in the allogenic and autogenic pathways. Surprisingly the terrestrial input of phosphorus from cultivated ponds, domestic sewage and Industrial effluents have been increasing recently which ultimately leads to the eutrophication in many aquatic environments (Rhytner and Dunston 1971; Golterman, 1973; Maher and Devries, 1994). An overall estimation reveals that sediment of Cochin region shows higher values of PO_4. Removal of phosphorus through terrestrial hydrodynamic regime also may play a pivotal role in the phosphorus loading of mangroves. The mangrove under the present investigation showed rich phosphorus value especially in Station-3 & 4 since is a favourable niche for flying fox (*Pteropus giganteus*) and painted bat (*kerivoula picta*), the excreta of these species enriched the phosphorus regime; besides the sewage runoff also influenced to enhance the general nutrient level inside the system. Baharudeen (1997) opined that contribution through sewage sludge, nutrient recycling by mangrove plants, increased biological production around mangrove zone and excretion of birds of typical mangrove environment are the main source of phosphorus in the ecosystem. According to Sheeba *et al.* (1996), Cochin backwater

receives amble input of the phosphorus through the effluent from the fertilizer company and this might be one of the major reasons for the enhancement of phosphorus at Cochin backwater and adjacent areas.

5.2.7.Potassium

The element, potassium is not precipitated by hydrolysis; it is presumed that in the clay fractions of those environments, the potassium bounded either by absorption or cation exchange process. (Goldschmidt, 1937; Heir and Adams, 1963). The potassium mainly comes into the sediments as a weathered product of Orthoclase, microcline and biotite (Nelson, 1962). In spite of the above source the mangrove sediments get addition of K through vegetal parts of mangrove flora (Deer *et al.*, 1962). Potassium of the area under investigation was found to be very high due to the silt fractions and weathering process. Panitz (1997) observed the variations in the elements of Na, K, Ca and P, show their great mobility and the phenomena of translocation and retranslocation, which may be a result of variations in the sources of these elements.

5.3.Phytoplankton

The most frequently occurring phytoplankton group in the mangrove ecosystem was the Chrysophytes, followed by Chlorophytes and Pyrrophytes and the best-represented family was Naviculaceae, followed by Nitzschiaceae, (Panitz, 1997). Similar microalgal profile was observed in the present investigation. Phytoplankton is the base of the food web in the aquatic systems. A large number of organic elements are required for phytoplankton growth. Diatoms essentially require silicon (Boyd, 1992). Accordingly the mangrove systems generally are rich in nutrient concentration, since the total output of phytoplankton are rather higher in this dynamic environment as reported by several workers in the past. In the Mangalavanam area was favourable for the abundance of phytoplankton due to its prevailed nutrient profile. The most frequently occurred phytoplankton in the stations were Chrysophytes, Cyanophytes, Chlorophytes and Pyrophytes, where as the best represented families were Naviculaceae, Nitzschiaceae and Coscinodisceae. Similar trend of occurrence of phytoplankton community in various mangroves was reported by Santhanam *et al.*, (1975); Panitz (1997) and Shajina (1992). In the Chrysophytes

group the genera *Pleurasigma, Gyrosigma, Navicula, Nitzscia, Coscinodiscus and Skeletonema* were predominant. As a general trend nutrients such as Nitrogen and Phosphorus are most likely to limit phytoplankton growth in aquatic medium. According to Boyd, (1992), diatoms require fairly large amounts of nitrogen, and nitrogen often is as important or even more important than phosphorus as a limiting factor Lee and Choa (1990) observed water temperature also influence the plankton population. Therefore the plankton richness in Station-3&4 portrayed the rich concentration of nitrogen as well as phosphorus, hence the species richness, diversification and abundance were slightly high. Diatoms constitute the major portion of the total phytoplankton composition. They require silicon also essentially for their growth; hence rich silicon concentration promotes growth of diatoms- Chrysophytes. The group of Dinoflagellates- Pyrophytes was most frequent during high tide and occurs predominately in seawater. The most frequently occurred genera in this family were *peridinum*, which has marine affinity. The Cyanophytes was represented by *Oscillatoria* is the characteristic species of freshwater and this was the group most frequently found during low tides at the stations and Cyanophytes group predominated in locations rich in organic matter. The genus *Oscillatoria* exclusively indicates the presence of domestic and industrial effluents (Panitz, loc.cit). *Scenedesmus* representing the Pyrophytes group explicit the characteristic of freshwater contaminated by high mineral content. Similar studies on plankton have been carried out by various researchers in mangrove and brackish water; prominent among them are Santhanam *et al.* (1975); Grindley Richard, (1984); Palaniappan and Baskaran (1985); Panitz (1997). DO, Nitrate and Phosphate are the environmental factors that influence phytoplankton propagation. The phytoplankton growth would be longer with low biomass (Uribe, 1988). The importance of nitrate in productivity and plankton biomass was shown by Biggs (1992). Takamura *et al.* (1992) observed a shift from one phytoplankton group to another accompanied by transition from nitrogen dependence to phosphorus dependence.

5.4. Zooplankton

Mackar (1992) observed that zooplankton biomass and species composition differed sharply between various region along with changes in temperature, salinity, nutrients and phytoplankton distribution. Sarkar *et al.*, (1985) opined that salinity controls the distribution of marine forms of zooplankton. In the

present study also observed that total zooplankton population showed a linear relationship with salinity. Comparatively Station-1 had maximum density of total zooplankton, due to the proximity to sea. Post monsoon season effected a slight declining trend at the beginning but later stabilized. Higher population was observed during March, April and May, which might be due to the higher salinity that favoured marine species and the evaporation increased the salinity in ecosystem. Garcia- Soto *et al.* (1991) based on satellite image found that zooplankton abundance were confined to low salinity in shore areas while sardine larvae did not show any clear relationship with hydrographic parameters. Qasim (1977) opined that the representation of zooplankton organisms in the mangrove swamps was few in numbers and groups and their role in the food chain was meagerly understood. Hence comparatively Station-3&4 observed a lower total count of organisms probably as the area is very shallow, salinity fluctuation, and subjected to freshwater influx and pollution impacts in the system. Prabhakaran *et al.* (1990) reported that in the study area the salinity was even 2ppt during peak monsoon months. Copepods dominated among the zooplankton community of all the Stations, followed by Decapods, Polycahetes, Amphipods, Cladocerans, Fish larvae and Eggs, which is in accordance with Shajina (1993), who reported similar zooplankton composition in the Cochin mangrove in their works. The abundance of matured and egg bearing copepods in the sample is an indication that mangrove areas are the ideal sites for their breeding, feeding etc. as reported by Ambler *et al.* (1991) and Sameote and Herman (1992). Srinivasan and Santhanam (1991) were found very rich zooplankton population in Pulluvazhi backwater and they attributed this abundance to macrozooplankton particularly copepods larvae and molluscan veligers. The microzooplankton, which observed in mangrove were Tanaids, Actinarians, Halobetes, Aplysia and Flatfish larvae with sporadic occurrence in the sample. The groups of larvae of finfish and shellfish obtained were mainly fresh water and estuarine species. The highly complex of mangrove environments seems to alter the zooplankton composition from time to time. The zooplankton density was less when compared to adjacent water like estuaries and backwaters (Shajina, 1993).

5.5. Macrobenthos

Benthic faunal assemblage is as essential tool for assessing the fishery potential of an area (Pillai, 1977). Macrobenthos of Indian coast and inshore waters

were studied by various researchers like Desai *et al.* (1967); Kurian (1953); Cherian (1967); Pillai (1977); Patra *et al.* (1988, 1990) and Sunilkumar (1993). Patra *et al.*(1988) stated that the common macrobenthic forms were Polychaetes, Crustaceans, Nemartines, Actinarians, Molluscs and Gobids in coastal zone of West Bengal and also he concluded that polychaetes were the dominant form of the macrobenthic group. (Pillai, 1977) reported that polychaetes were dominant among the macrobenthic fauna of Cochin backwater followed by mollusca. The results are in accordance with the facts revealed by the various authors, in which Polychaetes dominate the benthic population in all along the stations during the initial period of investigation probably due to the soil composition and the pollution impacts. As a general rule polychaetes are rich in anthropogenically polluted environments and is an indication of sewage pollution as reported by several authors. The soil composition in the area primarily constituted by sand and silt. Panikkar and Aiyar (1937) observed absence of animals on substrat of thick clay and their abundance on loose substrate. Pillai (1977) observed, largest benthic population between December and April where as minimum during Southwest monsoon. Desai and Krishnankutty (1967) also reported a marked decline of macrofauna during southwest monsoon in Cochin backwaters. Among the groups decapods were higher and represented by shrimps and brachyura larvae, which could tolerate wide variation of salinity, since they are euryhaline organisms. During high tide they enter into the mangroves due to their burrowing habit and nocturnal behaviours helped to settle the settlement at the benthic area of the stations. Gastropods and bivalves represented in less numbers, since those are filter feeders. Rarely the seeds of bivalves were brought to the shore by tides and settled at the bottom.

5.6.Finfish

Mangrove ichthyofauna with reference to the bioecology of mugilidae was studied by Ribieiro, (1989). Clezar (1990) analyzed the distribution and abundance of the family Engraulidae in mangrove areas. The Kerala government protects the Study area Mangalavanam and its kept under the control of Kerala Forest department and fishing activities are strictly prohibited. The fishes caught in Station-1&2 were generally with in the size range of 10cm to 15cm length, therefore this size groups were not readily acceptable market. The local fishermen usually collect the brackishwater fish seeds and being sold in the nearby island namely

Vypeen for farming activities. According to the earlier reports the occurrence and collection of milkfish juveniles in India are from April to July, where as grey mullets *L. macrolepis, L. parsia, L. tade* are abundant from October to February. The fry and fingerlings of pearlspot occur through out the year with a peak from April to July. The fry and Fingerlings of sandwhitting (*Silago sigama*) are available in good numbers through out the year with a maximum availability from January to May. The fry and fingerlings of Seabass occur from October to February and May to September. The seed of red snapper are available from January to June and September to October. The fry and fingerling of grouper and seabream are available from January to April (Silas, (1989); Nammalwar, (1986); Nammalwar *et al.*(1991) Rengaswamy *et al.*(1996). In the present studies, it has been observed a species diversity of finfish in the same magnitude as cited above. Fishery potential of Mangroves in the Kerala state was given by Purushan (1989). Ramachandran *et al.*(1985) attempted some environmental aspects of mangrove ecosystem in Kerala state. Fifty-two species of fishes were known to occur in Kerala in association with the mangroves. To sum up the results on ichthyofauna in Mangalavanam in general are in accordance of the authors mentioned above.

5.7. Crustaceans

Chakraborty and Chaudhery (1985) studied the distribution of fiddler crabs in Sunderbans. Community structure and assemblage of economically important benthic penaeid and non-penaeid juvenile prawns from the biotope in Portonova has been studied by Sambasivam and Krishnamurthy (1986). Chakraborty and Choudhury (1992) have elucidated the zonation of Brachyuran crabs in Sunderban mangrove ecosystem. Macintosh (1979) discussed about the predation of fiddler crabs (*Uca spp.*) in estuarine mangroves. Kurian (1984) observed the occurrence of the larval forms of some species of fishes and prawns in the Cochin estuaries. Jayson (1999) quoted that the people in the surrounding areas of Mangalavanam depend heavily on the various resources. Fishery potential is exploited by the local people and crab hunting; using lines is a regular practice. With this back ground information it can safely be concluded that area is a conducive environment for the shy animals such as juveniles of euryhaline crabs and shrimps, besides the ecosystem also may attract the animals by it's shallowness and as a good feeding ground. Panitz (1997) stated that the most economic shrimp and crab

species are less abundant in mangrove areas. Few resident species depend entirely on the mangrove ecosystem and among those crabs directly depend on mangrove areas for survival. They are adapted to the special sediment conditions, tidal fluctuations and varying salinities found in mangrove (Coelho, 1967). A distinct arboreal phenomenon of typical Sesarma spp. was found in some pockets of Mangalavanam. According to Vaninini *et al.* (1997) *Sesarma leptosoma, S. brocki, S. elongalum* are truly representing the tree climbing habits. A description of the vertical migrations between the roots and the canopy by *Sesarma leptosoma* in Kenya was given by Vannini and Riwa (1994). The results reveal that the species diversity of crustacean in the Mangalavanam was fairly high from January to June 2002.

5.8. Bivalves

Kjefve (1997) opined that within mangrove soft-bodied animals and bivalve molluscs would be higher sensitive to temperature rise. The bivalves and other molluscs were poorly represented in the mangrove system. It appears that, the conditions in the ecosystem was not conducive for the propagation of bivalves.

5.9. Macrovegetation

Kurian (1984) reported the occurrence of *Acanthus ilicifolius, Avicennia alba, Rhizophora spp.* and *Bruguiera spp.*in Cochin estuary. Ramachandran *et al.*(1986) after a detailed survey along the entire coastal stretches of Kerala reported 39 species of mangrove plants along with the associated flora. They included some mew species that were not reported earlier. They considered two species such as *Syzgium travancorium, Ardisia litoralis* are unique to Kerala mangrove. Rajagopalan (1986) in an appraisal of the mangrove ecosystem in Cochin backwater suggested that they are formative mostly develops on small reclaimed or natural islands with the dominant vegetation constituted by species of *Acanthus, Excoecaria clerodendrum, Aegiceros Avicennia* and *Rhizophora.* Ramachandran and Mohanan (1986) reported that until a few centuries ago backwaters of Kerala were fringed with rich mangrove vegetation. An estimate based on authentic record of Blasco, (1975) indicated that there were about 70,000ha of mangrove in Kerala, which have been reduced to few hundred ha and largely confined to some estuaries and creeks. Mangroves along the west coast of India are considered as highly degraded areas (Blasco, 1975, 1977).

Sivadhasan, (1991) conducted observations on mangrove vegetation of present study area Mmangalavanam. Present investigation reveals Mangalavanam posses a very little diversity of macro vegetation. The threats as a result of anthropogenic interference are the deforestation, reclamation, pollution, and diversion of freshwater, which severely affected not only the biota but also it lead to shrinking of the Mangalavanam mangrove ecosystem. According to recent investigations 17 true mangrove species and 233 semi mangrove species are reported to occur in Kerala (Unni & Kumar, 1997). Eucalyptus and teak plantation, which is practicing recently adversely affect the true mangrove flora. Blasco (1975) and Sunilkumar (1993) reported that the slight sandy soils of Kerala facilitate the colonization of *Calophyllum inophyllum, Thespesia populnea, Terminalia catappa, Prosopsis, Acacia planifrons, Casuarina equisetifolia.*

5.10. Avian fauna

According to Jayson (1999) 18 species of the avian fauna was found in large numbers during May and July in mangrove and total no of 41 species of birds belonging to 25 families were reported in the area under present present investigation, which include terrestrial Crow, a ubiquitous species in tropical areas. Kurup (1996) reported several species of birds occurring in the mangrove patches all along the Kerala coast and also stated that based on available information 76 species are known to occur in association with the mangroves of the state. NEST (1993) published a list of birds found at Kumarakam. Mohandas *et al.* (1994) reported 57 species of birds occurring Asramam mangroves of Kollam. During the study period it was observed the presence of only very common birds of tropical areas in the Mangalavanam. Jayson (1999) provided a picture about the Avian fauna of Mangalavanam and also reported little cormorant with white feathers all over the body was recorded from the area. Ripley (1962) found the occurrence of liitle cormorant with white and brown feathers. (Jayson, 1999) has suggested that Mangalavanam could be declared as an International Bird Area (IBA) due to the presence of more than 1500 little cormorant and the presence of more than 1000 Black crowned Night heron, which form one percent of the total population.

Apart from this, Mangalavanam is the shelter for Indian flying fox (*Pteropus giganteus*), Painted bat (*Kerivoula picta*), Three striped palm squirrel

(*Funambhulus palmarum*), Hosue rat (*Rattus rattus*), Bandicoot rat (*Bandicola spp.*) and common rat snake (*Pyras mucosus*).

5.11.Statistical Interpretation

Diversity indices are becoming quite popular among ecologists as tools for comparing different ecosystems. Diversity composed of two distinct components a) the total number of species b) evenness (how the abundance data are distributed among the species). The concept of species diversity in community ecology has been intensely debated over the years (Ludwig and Reynolds, 1988). As diversity indices incorporate both species richness and evenness into a single value. Peet (1974) termed these as heterogeneity indices.

5.11.1. Phytoplankton

In phytoplankton diversity, the index depicts a pattern of increasing with increasing trend from January to May in Station 3, as naturally that Station were flushed with surplus amount of nutrients especially phosphorus, nitrogen and silicate. But during June a sharp decline was observed in the species diversity probably due to adverse environmental condition for some species. By the Hill's number we could be able to infer the number of abundant species and very abundant species. Hence 12 numbers of very abundant species found to be maximum in the Mangalavanam ecosystem of interest, which represented in the Station-3.

Richness indice measures the species richness that is independent of the sample size. These indices are based on the relationship between total number of species recorded-S and total number of individuals-n, which increases with increasing sample size. R_1 and R_2 values also project same regime like diversity fluctuation. R_1 and R_2 could be used when the number of species is linearly related to sample size.

According to Ludwig and Reynolds(1988), when all species in a sample are equally abundant, it seems intuitive that an evenness index should be maximum and decrease toward zero as the evenness where E_1, E_2 & E_3 are highly sensitive to species number with the result even the occurrence of a rare species in very small

number may change the values rapidly, while E_4 &E_5 being ratio remain more or less stable and in that sense they are more reliable. E_5 is known as the modified Hill's ratio. Alatalo (1981) showed that E_5 approaches zero as a species becomes more and more dominant in a community. Present study exhibit the Station-4 evenness followed by Station-3 are found to be sound enough than other stations.

5.11.2. Zooplankton

Zooplankton diversity indices value exhibit a higher degree of diversification in February in Station-1 and April month in Station-4, which were probably due to the breeding season of various organisms in the food web;

Zooplankton richness index (R_1, R_2) values indicate a value shift in February and April likely due to the salinity regime and which support a linear relationship with the richness of the ecosystem. Station 4 also exhibited the same pattern. A good evenness was observed in Station-3 followed by Station-1& 2.

SUMMARY

Summary

Biodiversity of a mangrove ecosystem, Mangalavanam in the Cochin City has been conducted from January to June 2002. The present work is an effort on general ecological condition prevailing in the Mangalavanam mangrove ecosystem and their impacts on the biodiversity during the year 2002

Tidal water enter in to the mangrove through a canal from the Vembanad lake, therefore the salinity is always comparatively low which is evidenced by the emergence of terrestrial vegetation in the mangrove ecosystem.

True mangrove vegetation is represented by *Avicennia marina, Rhizophora mucronata and Acanthus ilicifolius.* The littoral flora comprises *Tectoma grandis, Mangifera indica, Swietenia macrophylla, Artocarpus hirsute, Hydnocarpus laurifolia,* and *Artocarpus heterophyllus*, which showed decrease of salinity in the water. The present study shows that while species diversity is less, population density of available species are more.

Avian fauna comprised mostly species of little cormorants (*Phalactocorax niger*) and blue crowned night herons (*Nycticorax nycticorax*). The other arboreal fauna was dominated by Indian flying fox (*Pteropus giganteus*).

The microalgae was dominated by species of Bacillariophyceae, which reveals more amount of silicate in the water, since silicate is essential for skeletal formation of diatoms. The respiratory demand of the aquatic community was more which was evidenced by average DO content of 3.5ml/l, despite the fact that phytoplankton was abundant in the water.

Zooplankton community comprised copepods, amphipods, decapods, cladecera and mysids. The benthic community was dominated by polychaetes and decapods.

The finfish fauna comprised mostly brackishwater species such as *Chanos spp., Liza spp., Etroplus spp., Silago spp., Lethrinus spp.* and *Lutjanus spp.*

The Crustacean fauna was dominated by *Penaeus spp., Metapenaeus spp., Macrobrachium spp., Acetes spp., Metaplex spp., Sesarma spp., Uca spp.*, and *Scylla spp.* The molluscan fauna was very poorly represented.

A comparison between the present data and the past reveals that the mangrove area has been shrinked and number of resident species has been vanished. The major cause of the general degradation in anthropogenic activities, which resulted heavy cultural eutrophication in the ecosystem

Trapping the juveniles of finfish and shellfish with different type of gears during the migration has also adversely affected the general fish fauna of the ecosystem.

Topographical survey reveals that there are scopes for afforestation with true mangrove plants such as *Rhizophora spp.* for the reclamation and restoration of the naturality of this small saline biotope.

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